AN ABSTRACT OF THE THESIS OF

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N.H. Anderson

Stream-restoration projects are usually designed to improve habitat quality for fishes. These projects manipulate flow patterns, substrate distribution, and amount and placement of large woody debris. Consequently, they also affect the size and composition of the aquatic macroinvertebrate community. This research evaluates two types of fish habitat restoration: off-channel structures (alcoves) and in-channel structures (log weirs). I compared macroinvertebrate habitats and communities in natural and artificial alcoves in Upper and South Fork Lobster Creeks, Lane Co., and examined the effects of log weirs on in-channel habitat diversity, community composition, drift patterns, and fish consumption of macroinvertebrates. Macroinvertebrate samples were collected from artificial and natural alcoves using hand pumps and D-nets. Within the channel, macroinvertebrates were collected from restored and unrestored reaches with a Hess sampler and using a stratified random sampling scheme. Forty-eight hour invertebrate drift samples were obtained at outlets of log-weir pools. Stomach contents were obtained from coho salmon (*Oncorhynchus kisutch*) and cutthroat trout (*O. clarki*) in restored reaches.

Although natural alcoves differed from artificial in location within the floodplain, morphology, permanence, and degree of interaction with the stream channel, both alcove-types provided similar habitats and contained similar macroinvertebrate communities. Average densities and diversity within the alcoves depended on habitat and time of year. Average densities were higher in artificial than in natural. Alcoves contained 29% of species richness within Upper Lobster Creek.

Within the stream channel, the diversity of macroinvertebrate habitat was lower in restored than in unrestored sections. Log weirs were associated with reduced taxonomic and functional feeding-group diversity. Composition of drift was not significantly different in restored and unrestored areas; however, drift densities were significantly lower in restored reaches. Diets of fishes in restored areas were composed primarily of organisms produced from outside restored areas. Although in-channel structures may enhance physical habitat for fishes, they may alter or reduce the availability of food for fishes feeding on drifting invertebrates.

Recommendations are given for improving the design of stream restoration projects with respect to macroinvertebrates; however stream restoration should focus on restoring whole-system integrity and function, instead of targeting just one or two types of organisms.

Effects of stream restoration on macroinvertebrate communities in an Oregon Coast Range System

by

M. Jo Christensen

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APPROVED:

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DEDICATION

This thesis is dedicated to Bret Christensen for giving me the courage to try.

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GENERAL INTRODUCTION

Fisheries habitat restoration has grown to a multi-million dollar industry in the Pacific Northwest as government agencies, private organizations and industry attempt to restore depleted spawning and rearing habitat for salmonids. When evaluations of these fish-habitat projects are conducted, they are usually based on fish or geomorphological responses (Solazzi et al. 1987, House et al. 1985, Armantrout 1989). Since these projects manipulate flow patterns, substrate distribution, and amount and placement of large roughness elements, they also may affect macroinvertebrate habitat and, consequently, the size and composition of the aquatic macroinvertebrate community. While a few workers have addressed the effects of these projects on macroinvertebrates, their investigations focused primarily on fish responses, and comparatively little time or resources were devoted to the macroinvertebrates.

The emphasis on fish responses in evaluations of restoration projects is natural because the main purpose of these projects is to enhance fish habitat. Why then should effects of fish habitat restoration on macroinvertebrates be considered? Three reasons for concern are:

1. Biodiversity One of the primary reasons that restoration projects are undertaken is to protect and restore diversity among stream fishes, but most of stream biodiversity is

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represented by insects. Comparatively, fish contribute little to system diversity (Fig. 1). Thus, stream projects that alter habitats may significantly affect whole-system biodiversity.

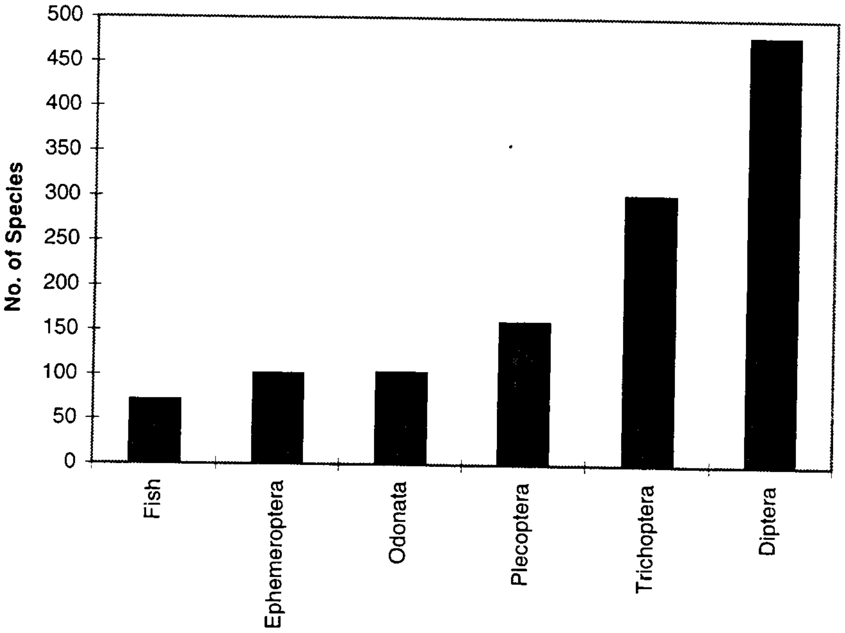


Figure 1. Richness of stream species in Oregon. Only major orders of macroinvertebrates are shown. Invertebrate numbers are estimated by J. Miller, Department of Entomology, Oregon State University. Estimates of fish numbers do not include exotics, and are estimated from Bond, 1994.

2. *Ecosystem Function* Macroinvertebrates constitute a major component of stream ecosystem function. They play a significant role in degradation of detritus by reducing particle sizes and preventing the accumulation of organic debris in streams (Anderson and Sedell 1979). In the aquatic food web, they are the link between plant material and the rest of the stream ecosystem, freeing stored nutrients from plants and detritus and

releasing these back to the ecosystem. Additionally, filter-feeding insects such as black flies and net-spinning caddisflies clean and clear the water column through filtration of tremendous quantities of organic particles (Wallace and Merritt 1981).

3. *Food Supply* Many terrestrial organisms depend on aquatic macroinvertebrates as their primary food source, including varieties of birds, bats, amphibians, and small mammals. Aquatic insects are also the major food source that sustains most stream fishes. Thus, restoration projects that affect macroinvertebrate diversity and abundance may have serious implications for fish survival and production.

This research seeks to address the effects of fish restoration on macroinvertebrate communities in an Oregon Coast Range stream. First, I collected baseline data on macroinvertebrate habitat and communities in artificial alcoves, a new and little-used method of off-channel stream restoration. With respect to artificial alcoves, my objectives were: (1) to evaluate macroinvertebrate habitat created by artificial alcoves, (2) to measure macroinvertebrate abundance and diversity in the alcoves and to determine the contribution of alcoves to stream biotic diversity, and (3) to compare the above parameters between artificial and natural alcoves. Second, I evaluated the effects of the most commonly-used form of fish habitat restoration, in-stream structures, on macroinvertebrate communities. With respect to in-stream structures, my objectives were: (1) to evaluate their effects on the availability and distribution of macroinvertebrate habitat, (2) to measure their effects on macroinvertebrate abundance (with emphasis on potential fish food organisms), drift abundance, taxonomic diversity and functional feeding group diversity, and (3) to evaluate the contribution of invertebrates produced in restored areas to fish diets.

STUDY SITE

The study was conducted during spring and fall in both 1994 and 1995 in Upper Lobster Creek and its tributaries, East Fork and South Fork Lobster Creeks. The watershed is managed by the Bureau of Land Management, and is located in the Oregon Coast Range, about 15 miles SE of Alsea, in Lane Co. The basin lies in the Tyee geological formation, which is resistant to weathering, resulting in steep topography. The basin also lies in the western hemlock *(Tsuga heterophylla* Sarg.) zone (Franklin and Dyrness 1969), but, as a result of forest management practices, is dominated by Douglas-fir (*Pseudotsuga menziesii* Mirb).

Ninety-two percent of the Lobster Creek basin has been logged over the last 50 years, and riparian zones have been high-graded for western redcedar (*Thuja plicata* Don). As a result, riparian vegetation is dominated by red alder (*Alnus rubra* Nutt), with occasional big-leaf maples (*Acer macrophyllum* Pursh), western redcedars or Douglas-firs. Additional data on physical features of the study sites are given in later sections. Since 1982, Upper Lobster Cr. has been the subject of intense fish-habitat restoration. Many in-channel structures (log and boulder weirs) have been installed in the stream to trap spawning gravel and to create rearing pools for anadromous salmonids (Fig. 2). Additionally, in 1990, BLM fishery biologists constructed a series of 8 artificial alcoves in off-channel areas along Upper and South Fk. Lobster Cr. (Fig. 3). The alcoves were designed to provide winter rearing habitat for coho salmon (*Oncorhynchus kisutch*). In-channel structures also were installed in E. Fk. Lobster Cr. in 1981 (House et al. 1986), but most of these structures were installed below my E. Fk. Lobster sites and, by 1994, no but most of these structures were installed below my E. Fk. Lobster sites and by 1994, no evidence of these structures remained.

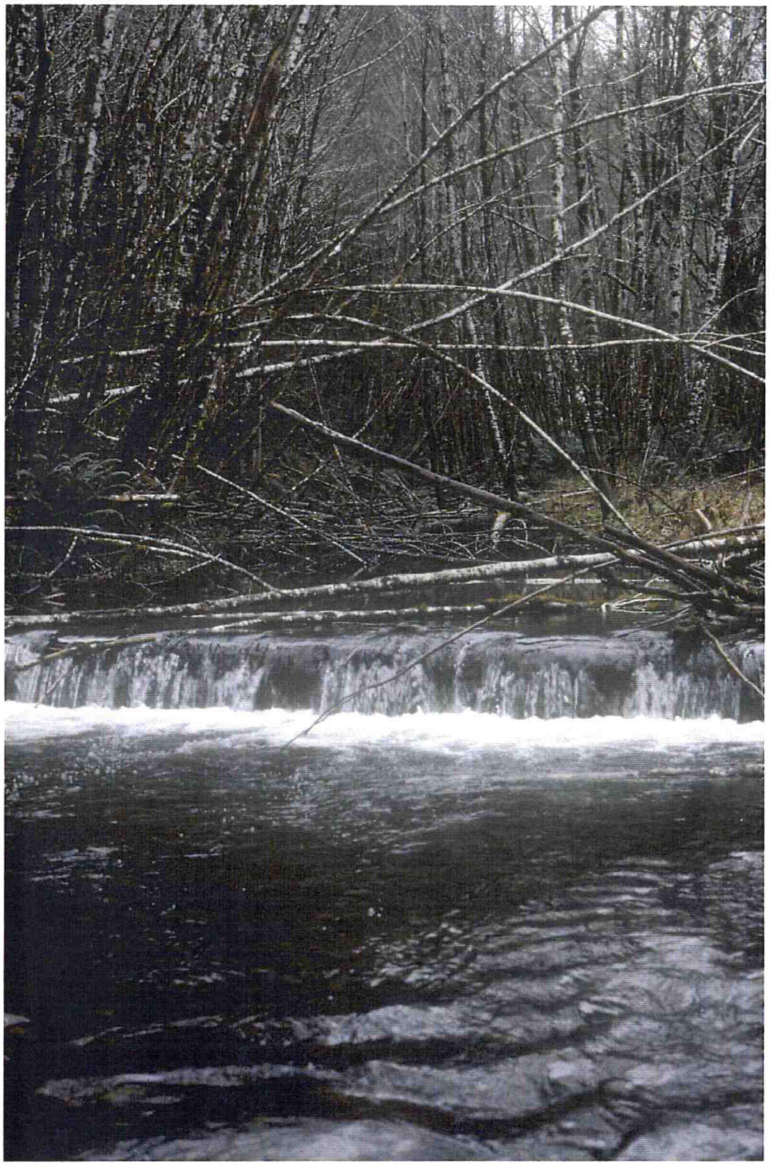


Figure 2. In-channel structure (log weir) on Upper Lobster Creek, Lane Co., OR., 1994.

Figure 3. Off-channel structure (artificial alcove) on Upper Lobster Creek, Lane Co., OR., 1994.

PART I

OFF-CHANNEL STRUCTURES

INTRODUCTION

An alcove is a stream habitat-type, defined as an area of "slack water along the channel margin, separated from the main current by streambanks or large channel obstructions such that they remain quiet even at high flows" (Bisson et al. 1982). Natural alcoves are created when aggregations of large wood or beaver activity result in impoundment of water along a stream margin (Fig. 7). They may also occur when water is impounded in remnant secondary channels or alluvial fans. Historically, alcoves probably were numerous in Oregon Coast Range streams (Sedell et al. 1982) and especially in coastal valleys where streams meandered across wide floodplains.

Because alcoves are protected from all but extremely high flows, they provide important rearing and overwintering habitat for juvenile coho salmon (Nickelson, et al. 1991a). However, activities such as logging, stream-cleaning, road-building, and extirpation of beaver have eliminated much of this habitat-type in Coast Range streams. Currently, the production of wild coho in Oregon coastal streams is thought to be limited by inadequate winter habitat (Nickelson, et al. 1991b).

The recognition of the importance of off-channel habitats for coho production has resulted in several projects designed to provide or enhance these areas. There have been several evaluations of these projects based on fish responses (Bustard et al. 1975, Peterson 1985, Nickelson, et al. 1991a and 1991b), but use of these projects by other organisms, including macroinvertebrates, has not been investigated. In my research on off-channel structures, I sought to answer the following questions:

(1) how do alcoves function in the Upper Lobster Creek system?

(2) what types of habitats do alcoves provide for aquatic invertebrates?

(3) what types of macroinvertebrates and communities live in alcoves?

(4) how do natural and artificial alcoves differ with respect to the above?

(5) do artificial alcoves really mimic the ecological function of natural alcoves?

OFF-CHANNEL METHODS

Alcove Selection

Eight artificial and six natural alcoves were used for study; this represented all natural and artificial alcoves present along Upper and South Fork Lobster Creeks at the time of this study. During sampling periods in September, some of the natural alcoves were dry and unavailable for macroinvertebrate sampling.

Habitat Identification

Macroinvertebrate habitat-types were identified in both natural and artificial alcoves. These were the depositional area, riffle-outflow, benthos, wood, and bank (Table 1; Fig. 4). Those comprising less than 2% of the total alcove area were lumped with others. The number of habitat-types present in an alcove depended on flow level and condition of the alcove inlet.

ALCOVE HABITAT-TYPE	**DESCRIPTION**	**DEPTH**	**AREA SAMPLED**	**SAMPLING METHODOLOGY**
Depositional Area	Interface between moving and standing water at inlet where coarse particulate organic matter (CPOM) accumulates.	0.15-0.50 m	0.0625 m^2 rectangle, randomly-selected, delineated by weighted PVC quadrat	Pumped contents of transect into bucket with hand-operated bilge pump. Filtered material through 500 micron sieve. Material was subsampled in field when volume exceeded that of sieve.
Riffle Outflow	Present in alcoves "perched" above floodplain, where water flows from alcove to stream. Shallow riffle over gravel and cobble.	0.05-0.10 m	0.250 m^2 square, randomly-selected, delineated by weighted PVC quadrat	Large substrates were hand washed in D-net (0.60 mm mesh) and removed. Remainder of area was disturbed to 6 cm depth and collected in net. Material was filtered through 500 micron sieve
Benthos	Bottom of alcove	0.25-3.0 m	0.0625 m^2 rectangle, randomly-selected, delineated by weighted PVC quadrat	Pumped contents of transect into bucket with hand-operated bilge pump. Filtered material through 500 micron sieve. Material was subsampled in field if volume exceeded that of sieve.
Wood	Large pieces (alder and conifer) placed in alcove. Usually covered by algae and partially buried under sediments.	0.10-3.0 m	0.05 m^2 cylinder	Two 0.05 m^2 alder cylinders were conditioned for 4 months and then suspended in each alcove, in a randomly-selected location. At each sampling interval, one cylinder was removed from each alcove, scrubbed in a bucket and replaced. Bucket contents were filtered through 500 micron sieve.
Bank	Alcove edge, characterized by thick emergent macrophytes and bank vegetation (sedges) hanging in water.	0.00-0.30 m	0.15 m^2 square, randomly-selected, delineated by weighted PVC pipe quadrat	D-net (0.60 mm mesh) was used to sweep area in transect. Net contents were washed in bucket and filtered through 500 micron sieve.

Table 1. Alcove habitat-types: description and sampling methodology.

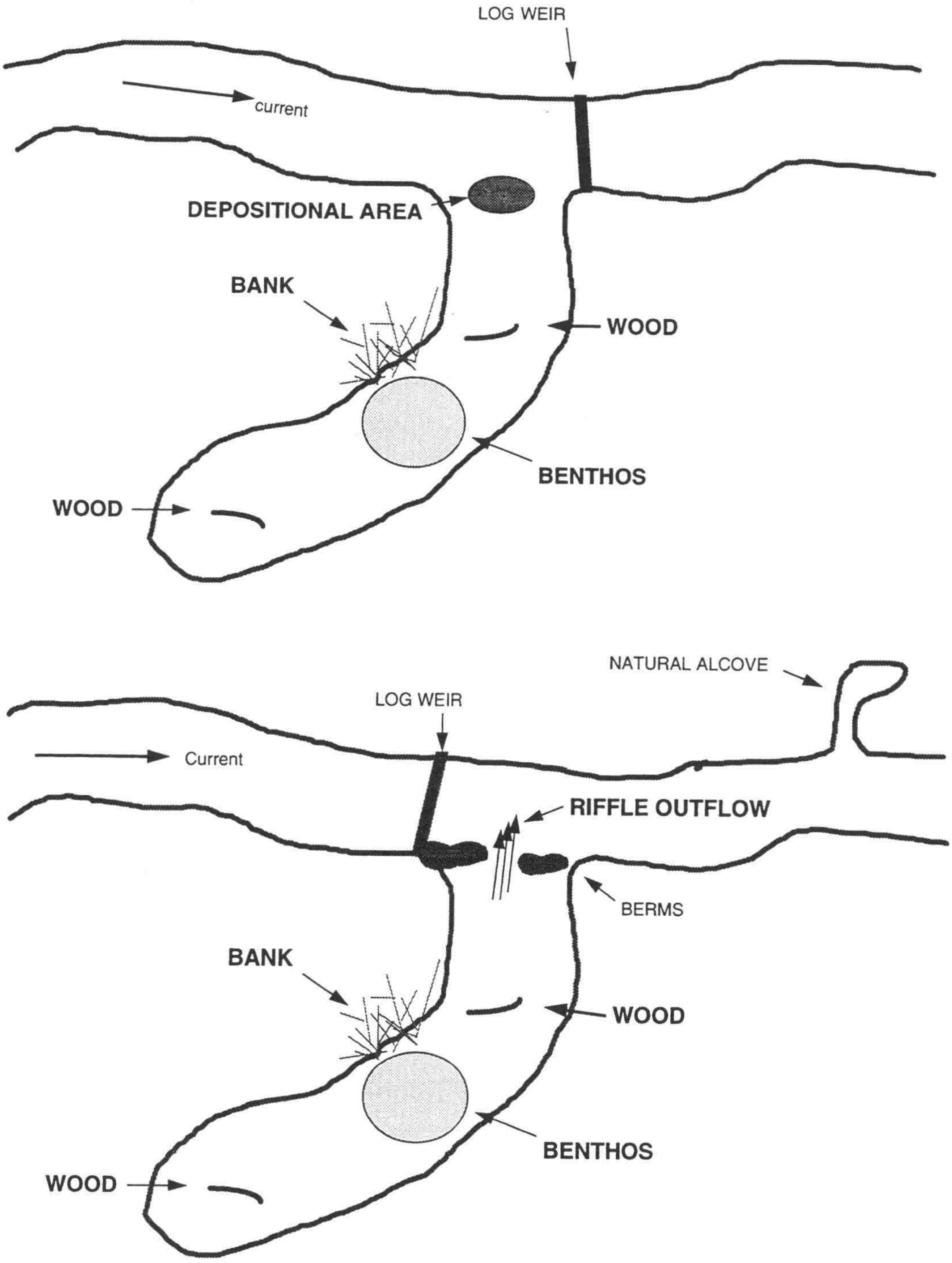


Figure 4. Habitat-types in normal (top) and "perched" (bottom) artificial alcoves. Habitat-types shown in bold-face. Natural alcove is shown only for scale.

Macroinvertebrate Sampling

Macroinvertebrates were sampled from each habitat in all alcoves during April, July and September of 1994. Refer to Table 1 and Figs. 5-6 for details regarding sampling methods. In artificial alcoves, macroinvertebrate sampling presented a number of logistical difficulties. For example, it was difficult to sample benthos habitats in many areas of artificial alcoves, since the depth was considerably over my head. The accumulation of fine sediments in artificial alcoves was tremendous; in addition to difficulties from becoming trapped in the sediments and having to be rescued by a colleague, each time the sample quadrat was pumped, approximately 5 gallons of "sludge" were collected.

Macroinvertebrates were preserved in 95% ethanol, counted, and identified to subfamily for Chironomidae and genus when possible for other organisms. Each taxon was assigned to a functional feeding-group following Merrit and Cummins (1984) and Armitage, et al. (1995) (for chironomids). Macroinvertebrate community diversity was determined using the Shannon-Weaver Index (natural log), which incorporates taxonomic richness and evenness in a single summary statistic (Washington, 1984).

Habitat Identification

Alcove average temperature was determined at each sampling interval by averaging temperature measurements taken with a hand thermometer from several locations (alcove entrance, benthos, surface). Daily temperature fluctuations from June-September, 1995 were monitored in one artificial alcove using a Ryan Thermograph. Average alcove depth was determined at each sampling interval by averaging depth measurements taken from five locations (entrance, two benthos and two edge locations). Condition of inlet was determined at each sampling interval.

Figure 5. Sampling alcove benthos habitat with hand pump. Upper Lobster Creek, Lane Co., OR., 1994.

Figure 6. Sampling alcove bank habitat with a D-net. Upper Lobster Creek, Lane Co., OR., 1994.

Day and night dissolved oxygen levels in alcoves and adjacent stream -channels were determined in mid-July using a YSI model 58 dissolved oxygen meter. Dissolved oxygen measurements were made in the middle of each alcove, at the half-way point in the water column. The dissolved oxygen meter was re-calibrated before measuring each alcove, using percent saturation of an adjacent riffle in the main channel as a standard.

OFF-CHANNEL RESULTS

Alcove morphology and function

Almost all natural alcoves were located in broad valleys, usually in the old floodplains of stream channels. They were created by fluvial and beaver activity, and were relatively shallow and small (0.10- 0.50 times the active channel width). The position of natural alcoves in relation to the stream channel insured that during periods of adequate flow, the entrance was clear of sediments and water flowed freely from the channel into the alcove. Natural alcoves maintained a dynamic surface connection to the stream channel and conditions within them were closely tied to changes in the adjacent stream. As a result, natural alcoves were also highly seasonal; during the September study-interval, approximately half of natural alcoves were dry (Fig. 7; Table 2).

In contrast, artificial alcoves were constructed in relatively narrow valleys using large equipment (back-hoes and hydraulic excavators) (Table 2). In some cases, the alcoves were situated ("perched") above the floodplain water-table, and in these cases, water flowed out of the alcove, down to the stream below (Fig. 8). All alcoves were extremely deep and large, and in many cases, built on a scale greater than the stream's ability to support them. The position of half of the artificial alcoves in relation to the stream channel resulted in the deposition of sediments at the alcove entrance, eliminating surface connection to the stream for more than 6 months out of the year. Accumulations of these

Figure 7. Natural alcove in late summer on Upper Lobster Creek, Lane Co., OR., 1994. Water levels in alcove are very low and entrance is almost dry.

Alcove No.[1]	Valley Width[2]	Valley Form[3]	Adjacent Land Form[4]	Channel Form[5]	Alcove Form[6]	Alcove Constraint[7]
1N	broad	MT	Hillslope/High Terrace	Unconstrained-braided channel	Old channel	High terrace
2N	broad	MT	Low Terrace/High Terrace	Unconstrained-single channel	Old channel	High terrace
3N	broad	MT	Low Terrace/High Terrace	Unconstrained--single channel	Old channel,beaver activity, wood jam	High terrace
4N	broad	MT	High Terrace/High Terrace	Unconstrained-single channel	Old channel, wood jam	Wood jam, low terrace
5N	broad	MT	High Terrace/High Terrace	Alternating hillslope-terrace constrained	Beaver activity, alluvial deposition	High terrace
1A	narrow	MV	Hillslope/Hillslope	Constrained by hillslope	Artificial construction	Artificial berm
2A	narrow	MV	Hillslope/High Terrace	Alternating hillslope-terrace constrained	Artificial construction	Artificial berm
3A	narrow	MV	Hillslope/Hillslope	Constrained by hillslope	Artificial construction	Artificial berm
4A	narrow	MV	Hillslope/Hillslope	Constrained by hillslope	Artificial construction	Artificial berm
5A	narrow	MV	High Terrace/Hillslope	Alternating hillslope/terrace constrained	Artificial construction	Artificial berm
6A	narrow	MV	Hillslope/Hillslope	Constrained by hillslope	Artificial construction	Artificial berm
7A	narrow	MV	Hillslope/Hillslope	Constrained by hillslope	Artificial construction	Artificial berm
8A	narrow	MV	Hillslope/Hillslope	Constrained by hillslope	Artificial construction	Artificial berm

[1] Refers to alcove type: N=natural alcove; A=Artificial Alcove

[2] Width of valley floor. Narrow < 2.5 times active channel width; broad> 2.5 times active channel width

[3] Configuration of valley floor. MT=multiple terraces with surfaces varying in height and distance from channel; MV=moderately V-shaped valley (side slopes >30%)

[4] Land form adjacent to active channel margin on left and right sides, looking upstream

[5] Morphology of active channel

[6] Feature forming alcove

[7] Feature maintaining/protecting alcove

Table 2. Location of study alcoves and morphology of adjacent channels. Upper and South Fork Lobster Creeks, Lane Co., OR. 1994-1995.

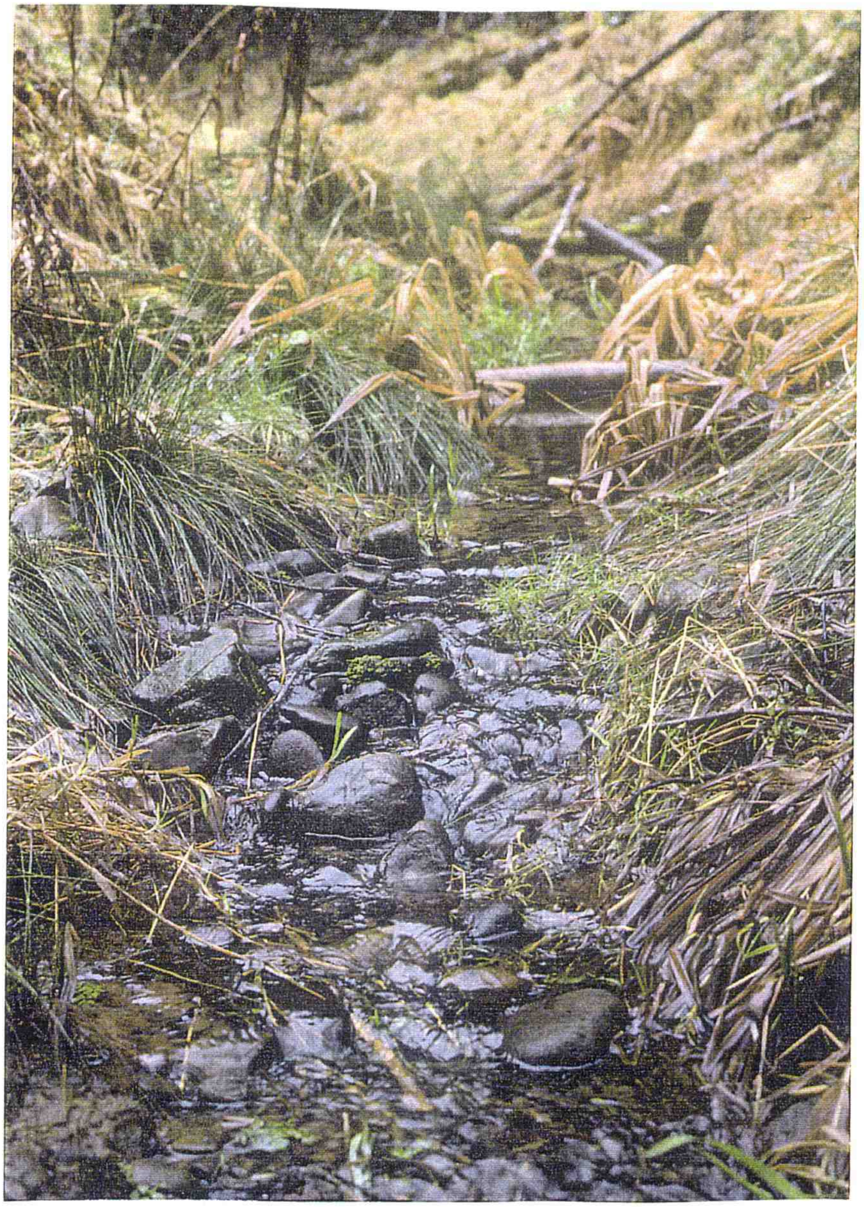


Figure 8. "Perched" artificial alcove on Upper Lobster Creek, Lane Co., OR., 1994. Water is flowing out of alcove, down to channel below, creating the "riffle-outflow" habitat.

sediments were highest when the adjacent log weir was placed *above* the alcove entrance instead of below. The combination of large size, depth, and presence of these sediments buffered conditions within the alcove against changes in the adjacent channel and eliminated the alcove's capacity to flush.

In natural and artificial alcoves, several of the habitat-types were lost when water levels dropped. For example, in natural alcoves, water-levels dropped below the level of aquatic and overhanging terrestrial vegetation, eliminating the bank area as habitat for aquatic insects. In artificial alcoves, sediment deposition at the alcove entrance prevented the accumulation of detritus, eliminating depositional areas. Finally, in both alcove-types, wood was occasionally eliminated as a macroinvertebrate habitat when beavers removed both large pieces of natural wood and the alder cylinders that were placed there for this study.

Temperature differed between the two alcove types. Because the hydrology of natural alcoves was closely linked to that of the stream channel, temperatures generally followed those of the stream. However, average temperatures were higher in September when many natural alcoves were very shallow and, in some cases, isolated from the cooler stream water. In contrast, the large size and depth of artificial alcoves resulted in relatively low water temperatures throughout the year (Fig. 9).

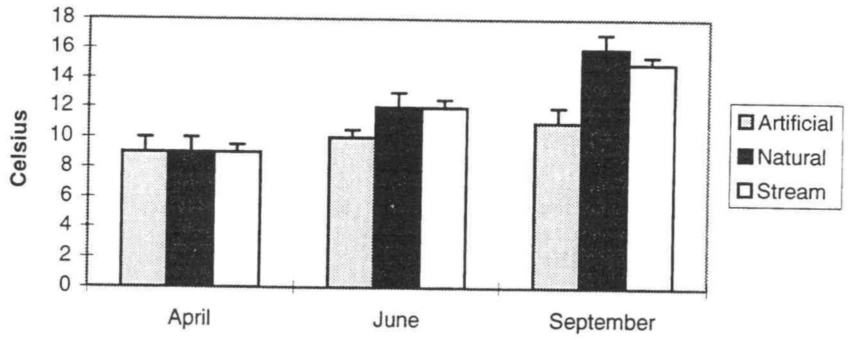


Figure 9. Mean temperature (+SE) in artificial and natural alcoves and adjacent stream. Alcove temperature based on average of measurements in several locations. Stream temperatures based on spot measurement in thalweg, upstream from alcove entrance. Upper and South Fork Lobster Creeks, Lane Co., OR, 1994-5.

In both alcove types, dissolved oxygen levels were low compared with those in adjacent stream channels. Surprisingly, during both day and night, dissolved oxygen levels were not significantly different between the two alcove types. Furthermore, among alcoves of the same type, levels of dissolved oxygen at night were not significantly different than day levels (Fig. 10).

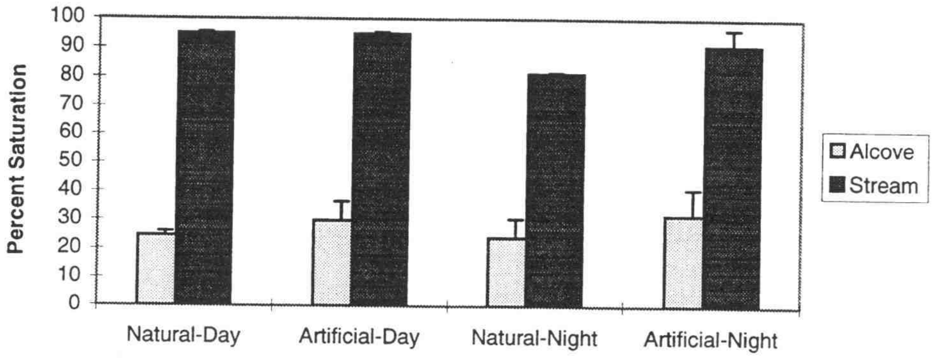


Figure 10. Mean levels (+SE) of dissolved oxygen in artificial and natural alcoves and adjacent stream channel. Upper and South Fork Lobster Creeks, Lane Co., OR. July, 1995

Macroinvertebrate Densities

Density of macroinvertebrates varied by alcove-type and habitat, with average densities higher in artificial alcoves than in natural ones. The riffle-outfall in perched artificial alcoves had the highest densities, while wood and bank habitats in both alcove types contained the lowest (Fig. 11).

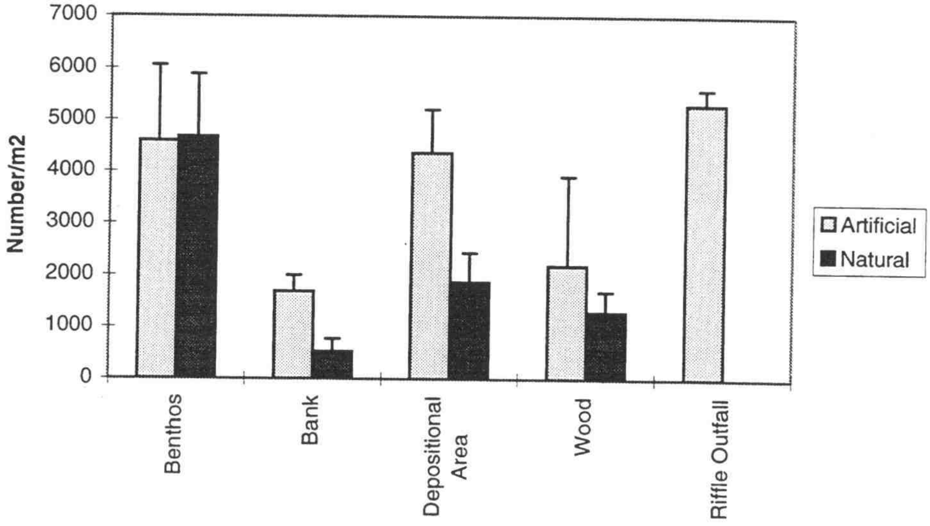
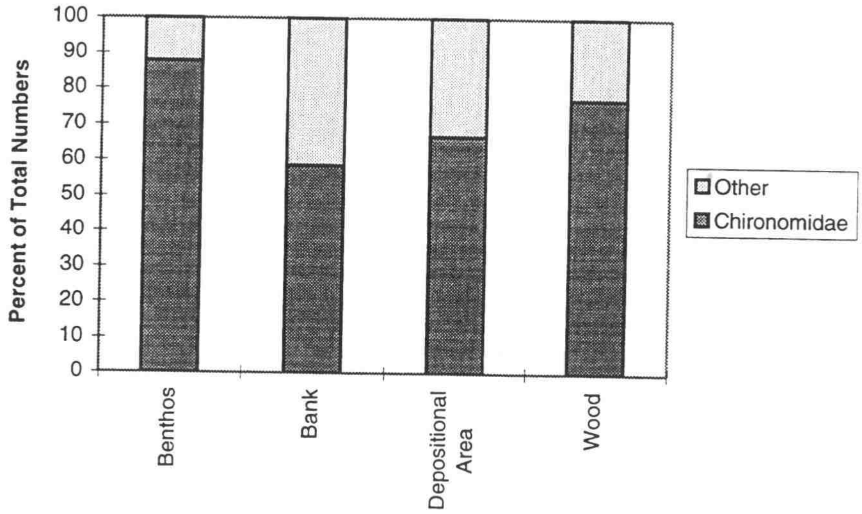


Figure 11. Mean density (+SE) of invertebrates in various habitats of artificial and natural alcoves. Upper and South Fork Lobster Creeks, Lane Co., OR. 1994. Data shown are combined from April, June, and September sampling intervals.

Community Composition and Diversity

Chironomids were the dominant taxon in all habitat-types in both kinds of alcoves (Fig. 12). After excluding chironomids, the remaining taxa varied by alcove- and habitat-type. Sphaeriid clams (*Pisidium*) were extremely numerous in all habitats of natural alcoves, while ceratopogonid flies were a dominant taxon in artificial alcove habitats (Table 3; Appendix 1).

A. Natural Alcoves



B. Artificial Alcoves

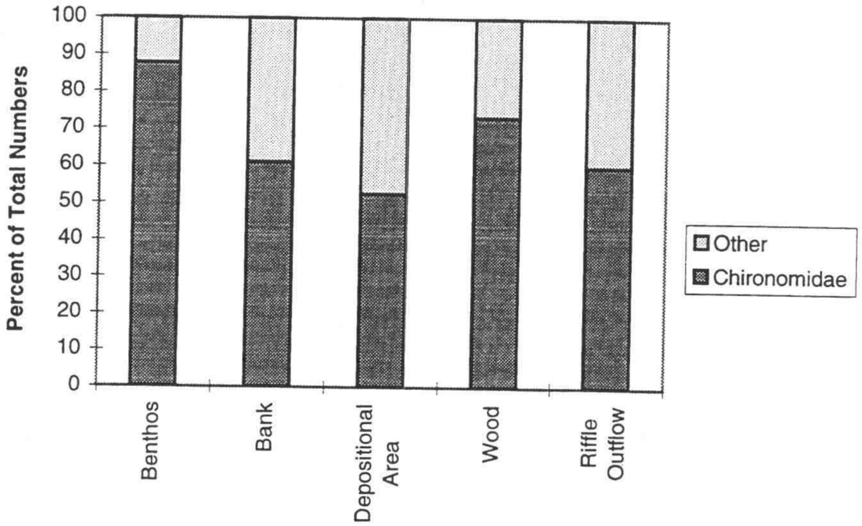


Figure 12. Abundance of Chironomidae compared to other taxa, by habitat, in artificial and natural alcoves. Upper and South Fork Lobster Creeks, Lane Co., OR., 1994. Data combine all seasons and are based on average number/m^2 of each taxon.

HABITATS	**ARTIFICIAL**	**%**	**NATURAL**	**%**
Benthos	Limnephilidae	22	Dytiscidae	3
	Ceratopogonidae	17	Ceratopogonidae	3
	Tipulidae	19	Culicidae	8
	Sphaeriidae	21	Pleuroceridae	11
	Misc.	21	Sphaeriidae	66
			Misc.	9
	MEAN DENSITY	675/m^2	**MEAN DENSITY**	631/m^2
Bank	Limnephilidae	11	Sphaeriidae	24
	Dytiscidae	11	Misc.	76
	Ceratopogonidae	21		
	Misc.	57		
	MEAN DENSITY	660/m^2	**MEAN DENSITY**	433/m^2
Depositional Area	Hydroptilidae	15	Ceratopogonidae	8
	Ceratopogonidae	21	Pleuroceridae	11
	Psychodidae	9	Sphaeriidae	35
	Pleuroceridae	4	Misc.	46
	Sphaeriidae	6		
	Misc.	45		
	MEAN DENSITY	1628/m^2	**MEAN DENSITY**	912/m^2
Wood	Ceratopogonidae	45	Ceratopogonidae	11
	Misc.	55	Sphaeriidae	16
			Misc.	73
	MEAN DENSITY	584/m^2	**MEAN DENSITY**	351/m^2
Riffle Outflow	Nemouridae	24		
	Uenoidae	28		
	Ceratopogonidae	4		
	Pleuroceridae	4		
	Sphaeriidae	6		
	Hydrachnida	3		
	Misc.	31		
	MEAN DENSITY	2,376/m^2		

Table 3. Proportions and mean density of dominant taxa, excluding Chironomidae, in artificial and natural alcoves. Upper and South Fork Lobster Creeks, Lane Co., OR, 1994.

Community taxonomic diversity (Shannon-Weaver H') varied by alcove- and habitat-types, and season (Fig. 13). When all seasons were combined, forming a "comprehensive snapshot" of community diversity, artificial and natural alcoves were quite similar. In April and June, community diversity was considerably higher in artificial alcoves, but the natural alcoves were more diverse in September. Wood habitats had the lowest diversity while bank habitats had the highest. The diversity rating for bank habitats was almost identical in both alcove-types (Fig. 13).

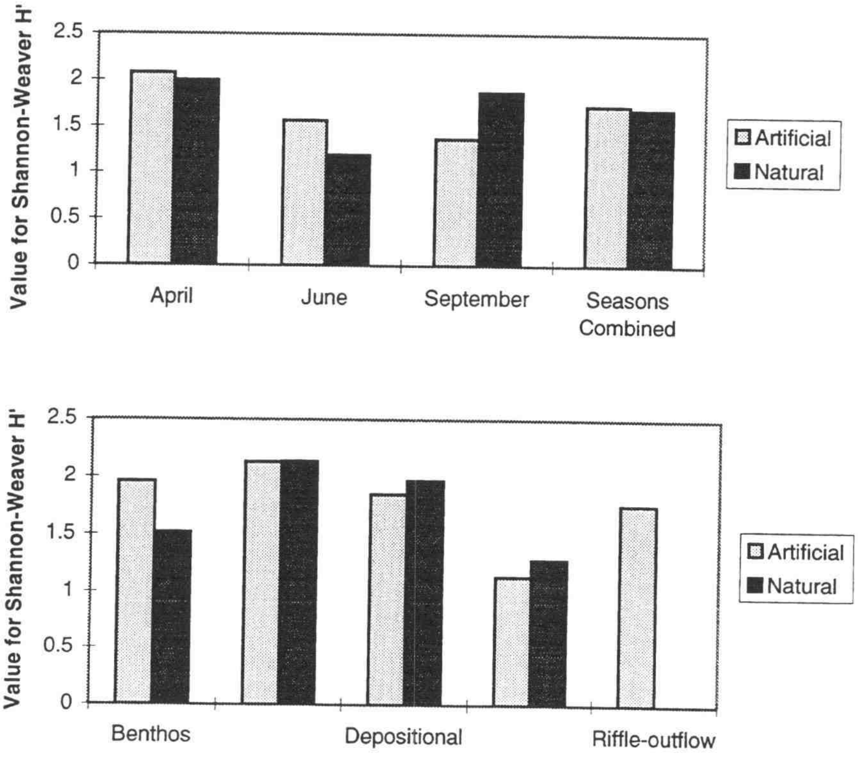


Figure 13. Community diversity in artificial and natural alcoves by season (top) and habitat (bottom). Upper and South Fork Lobster Creeks, Lane Co., OR., 1994.

Contributions to Biotic Diversity

Alcoves contained 28 genera that were very rarely collected or were not found elsewhere in the basin (including E. Fk. Lobster Cr.) in my surveys of 1994 and 1995, nor in surveys conducted earlier by the BLM (Table 4).

Ephemeroptera	Baetidae *Callibaetis*	Coleoptera	Dytiscidae
Odonata	Aeshnidae		*Agabus*
	Aeshna		*Hydaticus*
	Anax		*Hydrovatus*
	Coenagrionidae		*Hydroporus*
	Argia		*Liodessus*
	Zonagrion		*Oreodytes*
	Libellulidae *Libellula*		*Sanfilippodytes*
Hemiptera	Corixidae		*Uvarus*
	Corisella		Hydrophilidae spp.
	Hespercorixa	Diptera	Chaoboridae
	Gerridae *Limnoporus*		*Chaoborus*
	Nepidae *Ranatra*		*Mochlonyx*
Trichoptera	Leptoceridae *Triaenodes*		Culicidae
	Limnephilidae		*Culex*
	Asynarchus		*Culiseta*
	Halesochila taylori		Dixidae *Meringodixa*
	Limnephilius		
	Phyganeidae *Ptilostomus*		

Table 4. Contributions of alcove macroinvertebrates to aquatic biodiversity in Upper Lobster Creek, Lane Co., OR., 1994. Taxa listed were collected exclusively in alcoves, or found very rarely elsewhere in the basin during 1994 and 1995, nor in earlier surveys conducted by the BLM (Salem District Office, unpublished data).

OFF-CHANNEL STRUCTURES
DISCUSSION

Macroinvertebrate Habitat in Alcoves

In aquatic ecosystems, the nature and diversity of available habitats subsequently influences the size and composition of macroinvertebrate communities (Minshall and Rabeni 1977, Statzner and Higler 1986). Alcoves provide diverse macroinvertebrate habitats, delineated by flow condition, depth, substrates, and proximity to vegetation. Differences among the alcoves in the quality and availability in these habitats were reflected by differences in the macroinvertebrate assemblages dwelling within them.

Natural alcoves were relatively small in size, and their position in the floodplain enabled them to maintain a dynamic connection to the adjacent stream channel. As a result, the habitats and communities within them were strongly influenced by incoming flow from the stream channel. For example, when water-levels dropped in the stream, depths also dropped in natural alcoves, and various habitats (such as the bank and depositional area) were reduced or eliminated. In late summer, many natural alcoves were dry. In contrast to the seasonal nature of natural alcoves, habitat quantity and quality in artificial alcoves seemed rarely affected because they were isolated from hydrologic changes in the stream channel.

Macroinvertebrate Community Composition

Because natural alcoves were more profoundly influenced by conditions in the stream channel, they contained greater densities of lotic-associated taxa. Only eight taxa were found exclusively in natural alcoves: *Micrasema* (Brachycentridae), *Meringodixa*

(Dixidae), *Uvarus* (Dytiscidae), *Heterlimnius, Lara, Narpus*, (Elmidae), *Chrysops* (Tabanidae), *Antocha, Dicranota* (Tipulidae). At least six of these are associated almost exclusively with lotic-erosional habitats (Merritt and Cummins, 1984).

While there were profound differences in geomorphology and hydrologic function between the natural and artificial alcoves, both provided the same habitat-*types*. The primary difference among these habitat types was seasonality. As a result, macroinvertebrate communities in natural and artificial alcoves were similar in many respects.

For example, in April, when water levels were high in natural alcoves and all habitats were present, Shannon-Weaver community diversity was almost identical between natural alcoves. In mid-summer, community diversity was reduced in both alcove-types; however, it was substantially reduced in natural alcoves because low water levels limited habitat abundance. In September, diversity remained low in artificial alcoves, but increased substantially in natural alcoves. The increase in natural alcove community diversity was due to the deposition of a large number of lotic-associated taxa there, specifically first- and second-instar fall shredders and predators(mostly Trichoptera and Plecoptera). In contrast, very few of these taxa were able to penetrate into artificial alcoves, and September community diversity in these alcoves remained low.

In both artificial and natural alcoves, wood habitats contained the lowest community diversity and second lowest macroinvertebrate densities. This may be due to the fact some of the wood cylinders used for sampling often were covered by 1.0-5.0 cm of sediment, precluding their use as habitat for many invertebrates. It is interesting that of the taxa found on alcove wood, none is known to be wood-associated. Dudley and Anderson (1982) identified 56 taxa closely associated with wood, and 129 facultative users of wood in western streams. With the exception of chironomids, none of the taxa identified by them were commonly found on wood in alcoves. In fact, alcove wood communities more closely resembled alcove benthos communities.

Benthos communities had higher densities of chironomids than did any other habitats, with very little difference between artificial and natural alcoves in proportion of Chironomidae compared to other taxa (88 and 89%, artificial and natural respectively). This is not surprising because of the depths and fine substrates present in benthos habitats. However, of the remaining taxa in benthos areas, artificial alcoves were clearly more diverse than were natural alcoves, containing a mixture of Ceratopogonidae, Limnephilidae, Pleuroceridae (*Juga*) and others. In contrast, after excluding chironomids, natural alcoves were dominated almost exclusively by sphaeriid clams (*Pisidium*). The predominance of this clam in benthos habitats of alcoves is not surprising. *Pisidium* typically occurs in small ponds where water flow is negligible and substrates have low oxygen concentrations and high silt and organic content (McMahon, 1991). Additionally, unlike many macroinvertebrates, sphaeriids are able to filter-feed in deep standing water because of siphons which allow them to create feeding currents. (McMahon, 1991). As a result, they are one of the only filter feeders able to subsist in alcove benthos environments. The relative dominance of sphaeriids in natural alcoves compared with artificial alcoves may be explained by the ease with which they can colonize these habitats. Sphaeriids are often moved by water currents or transported phoretically on other invertebrates. The small size of natural alcoves combined with their close hydraulic connection to the stream channel facilitates the deposition of *Pisidium* within them.

In both alcove types, bank habitats had among the lowest percentages of chironomids (60 and 58%, artificial and natural, respectively), and the highest number of other taxa (78). In particular, Hemipterans were particularly rich (7 taxa) , as were Dixidae (3 taxa), Dytiscidae (8 taxa) and Limnephilidae (8 taxa). Additionally, banks were the only habitat whose densities of collector-filterers, shredders and predators approached or exceeded densities of collector-gatherers.

Richness of taxa and functional feeding-groups in bank habitats may be due to the fact that there were numerous microhabitat-types present within the habitat categorized as bank. These included the overhanging terrestrial vegetation, aquatic macrophytes and floating algal mats, as well as the bank-area benthos, surface film and the water column. High taxonomic and functional feeding-group richness observed in bank habitats may also be due to the fact that sampling in these included both the water column and bank-benthos. In contrast, other benthos and depositional area habitats were sampled primarily the alcove bottom.

Anderson and Wallace (1984) suggested that "the biomass and diversity of invertebrates associated with aquatic macrophytes in lentic or lotic habitats may exceed that of the fauna in the sediments at the same location." My results indicate that invertebrate diversity was higher in these macrophyte-rich habitats, and because larger aquatic invertebrates such as Anisoptera (Odonata), Dytiscidae (Coleoptera), and Hemiptera were numerous here, biomass was propbably high also. However, average densities observed in bank habitats were quite low. This was especially true in natural alcoves, where densities averaged only 400/m^2. Lower densities of invertebrates in bank habitats may be explained by the fact that I used a larger mesh size (0.60 mm) while sampling bank habitats than was used in other habitats (0.50 mm). Also lower densities in bank samples of natural alcoves may be explained by differences in the quality and quantity of bank habitats between the two alcove-types. In natural alcoves, reductions in water levels eliminated the connection between terrestrial vegetation and aquatic habitats, often leaving only bare soil at the alcove edges. Furthermore, bank areas in natural alcoves were often quite shallow, reducing space for microhabitat diversity. Finally, bank vegetation here was regularly thinned by beavers.

Depositional areas in both artificial and natural alcoves areas were characterized by relatively high community diversity. Chironomids accounted for a lower percentage of total density here (63 and 52%, artificial and natural, respectively) than in benthos, wood or riffle-outflow habitats. After accounting for chironomids, depositional area assemblages contained a mix of insects reflecting the transition from lotic to lentic habitats. For example, taxa typically associated with lotic habitats were common in depositional areas of both alcove-types, including a variety of Ephemeroptera, including *Attenella, Ephemerella, Serratella* (Ephemerellidae) *Cinygmula, Epeorus* (Heptageniidae), *Paraleptophlebia* (Leptophlebiidae), Plecoptera including *Sweltsa* (Chloroperlidae), *Malenka* (Nemouridae) and Perlodidae spp., and Trichoptera, including *Dicosmoecus* (Limnephilidae), *Micrasema* (Brachycentridae), *Neophylax* (Uenoidae), and *Rhyacophila (*Rhyacophilidae). At the same time, lentic-associated taxa also made up a large proportion of depositional-area taxa, including Sphaeriidae and Ceratopogonidae.

The riffle-outflow was present only in alcoves where direct connection to the stream channel had been eliminated by the formation of large sediment berms. Habitat in this area was characterized by shallow water running over relatively coarse substrates (gravel and cobble) and fairly dense macrophyte growth. As a result, macroinvertebrate communities in this habitat were a mix between lentic- and lotic-associated forms. For example, lentic Dytiscidae and Ceratopogonidae were fairly common (136 and 319/m^2, respectively), while lotic taxa such as *Malenka* (Nemouridae) and *Neophylax* (Uenoidae) also occured in high numbers (1742 and 2064/m^2, respectively). Riffle-outflows also contained the highest invertebrate densities of all alcove habitats, as well as the greatest proportions of collector-filterers, predators and generalists. High density and diversity of collector-gatherers in these areas is probably due to the range of microhabitats among the coarse substrates, which provides heterogeneous micro-sites for insect attachment and enable a variety of niches to co-exist (Ward, 1992).

In general, most alcove habitats were characterized by deep water with fine substrates, providing unsuitable conditions for many macroinvertebrate taxa and functional feeding groups. In these habitats, filter-feeding is ineffective for most insect taxa because of insufficient current, and low light and unsuitable substrates prevent algal growth necessary to support scrapers. Microbial respiration on accumulated organic sediments may create low oxygen concentrations at the sediment-water interface (Ward 1992, Pinder 1995). As a result, all alcoves habitats are dominated by one ecological guild (collector-gatherer FPOM feeders) and chironomids as the one taxon.

Some chironomids are uniquely adapted to survive in conditions provided by alcoves. Their tubes allow them to live a few millimeters above anoxic sediments and allow for specialized respiration movements (Elliott 1971, Pinder 1995). Additionally, some chironomid taxa, including those in the Chironomini and Tanytarsini, possess respiratory pigments, allowing them to provide oxygen to tissues when external oxygen sources are depleted (Walshe 1947, 1948; Eriksen et al. 1984).

Dissolved Oxygen

The lack of difference in dissolved oxygen between day and night in the alcoves is surprising. Typically, water bodies with well developed aquatic plant communities exhibit reduced oxygen levels at night when photosynthesis is exceeded by community respiration (Hynes 1970, Eriksen 1984). For example, Kushlan (1979) reported diel fluctuations in dissolved oxygen saturation from 200% (midday) to 4% (midnight) in a pond. In the alcoves, it is possible that water flowing in from the channel mixes with alcove water and replenishes oxygen. However, in perched artificial alcoves (where there is no surface link to the stream channel) concentrations of dissolved oxygen also remained high at night, indicating that subsurface flow from adjacent hillsides and hyporheic flow from the floodplain also may replenish and maintain oxygen levels.

In summary, artificial and natural alcoves were most different in terms of size, degree of hydraulic connection to the stream channel, and seasonality. Natural alcoves were more strongly characterized by lotic features and correspondingly, had a greater percentage of lotic-associated taxa. Artificial alcoves were more isolated from the stream-channel. Despite substantial differences in hydrology and function, however, both provided the same habitat-types; as a result, macroinvertebrate communities between the stream-channel. Despite substantial differences in hydrology and function, however, both provided the same habitat-types; as a result, macroinvertebrate communities between the two were not substantially different.

OFF-CHANNEL STRUCTURES
CONCLUSIONS

Do artificial alcoves mimic the ecological function of natural alcoves? The answer to this question, like most questions of ecology, lies in the interests and perspective of the one asking the question.

From a fisheries perspective, the primary ecological function of an alcove is to provide overwintering and rearing habitat for fish, and in particular, coho salmon. In this respect, artificial alcoves appear to closely mimic natural ones.

From a hydrologic perspective, natural alcoves are relatively small, shallow, transient features in aquatic ecosystems. They are present only at high and moderate flows, and maintain a dynamic surface connection to the stream channel. As a result, conditions in natural alcoves are closely tied to conditions in the stream channel. In contrast, the artificial alcoves of Upper Lobster Creek are extremely large, deep, permanent features, constructed in areas where alcoves would not exist naturally. In some cases they have been built on a size and scale greater than the stream's ability to support them, resulting in the elimination of both surface flow from the channel and the capacity to flush. As a result, conditions in artificial alcoves are independent of changes in the stream channel. Therefore, artificial alcoves do not mimic natural alcoves from a hydrologic standpoint.

The results of this study indicate that the macroinvertebrate communities of artificial alcoves do mimic the communities of natural alcoves in many respects. Artificial alcoves provided the same types of habitats for macroinvertebrate as do natural alcoves. These differed between the two alcove-types in size and lifespan, which resulted in differences in macroinvertebrate density and community composition. However, natural alcoves contained few taxa that were not found in artificial alcoves, and overall community diversity was almost identical between the two.

Artificial alcoves created or enhanced lentic habitats that have been eliminated from Upper and South Fork Lobster Creeks by the removal of alcove-forming elements (large wood jams and beaver) from the system. They contained organisms not found or rarely collected elsewhere in the basin. In so doing, artificial alcoves contributed substantially to biotic diversity in the Lobster Creek watershed.

PART II

IN-STREAM STRUCTURES

INTRODUCTION

Habitat for fishes in stream channels is created when large roughness elements (i.e., wood, boulders) provides physical structure that breaks up streamflow, traps sediments for spawning, and creates complex pools for rearing young fish. Likewise, large wood and boulders provide hydraulic and sediment complexity that, in turn, create a diverse assemblage of macroinvertebrate habitats (Fig. 14). Historically, stream channels in the Pacific Northwest were dominated by the presence of large woody debris (Sedell and Luchessa 1982, Sedell and Swanson 1984).

Programs of timber harvest and wood-debris removal over the last century have eliminated much in-stream structure, as well as riparian trees and snags that would provide future wood debris. Most stream restoration projects have attempted to recreate natural habitat conditions by installing in-stream, channel-spanning structures such as gabions, log and boulder weirs, log deflectors, etc. (Meehan 1991, Nickelsen et al. 1991b). The log weirs installed on Upper Lobster Creek are a typical example of these widely used structures (Fig. 15).

The use of these structures for stream habitat "improvement" is now widely accepted by land- and fisheries-management agencies in the western United States and Canada, and is an accepted management technique in the Pacific Northwest (Hall and Baker, 1982; Reeves et al. 1990). It is therefore important to evaluate the effects of these projects on non-target organisms, such as benthic macroinvertebrates. With respect to these in-stream structures, the objectives of my study were: (1) to evaluate their effects on the availability and distribution of macroinvertebrate habitat, (2) to measure their effects on macroinvertebrate abundance (with emphasis on potential fish-food organisms), drift abundance, taxonomic diversity, and functional feeding-group diversity, and (3) to measure the contribution to fish diets of invertebrates produced in these restored areas.

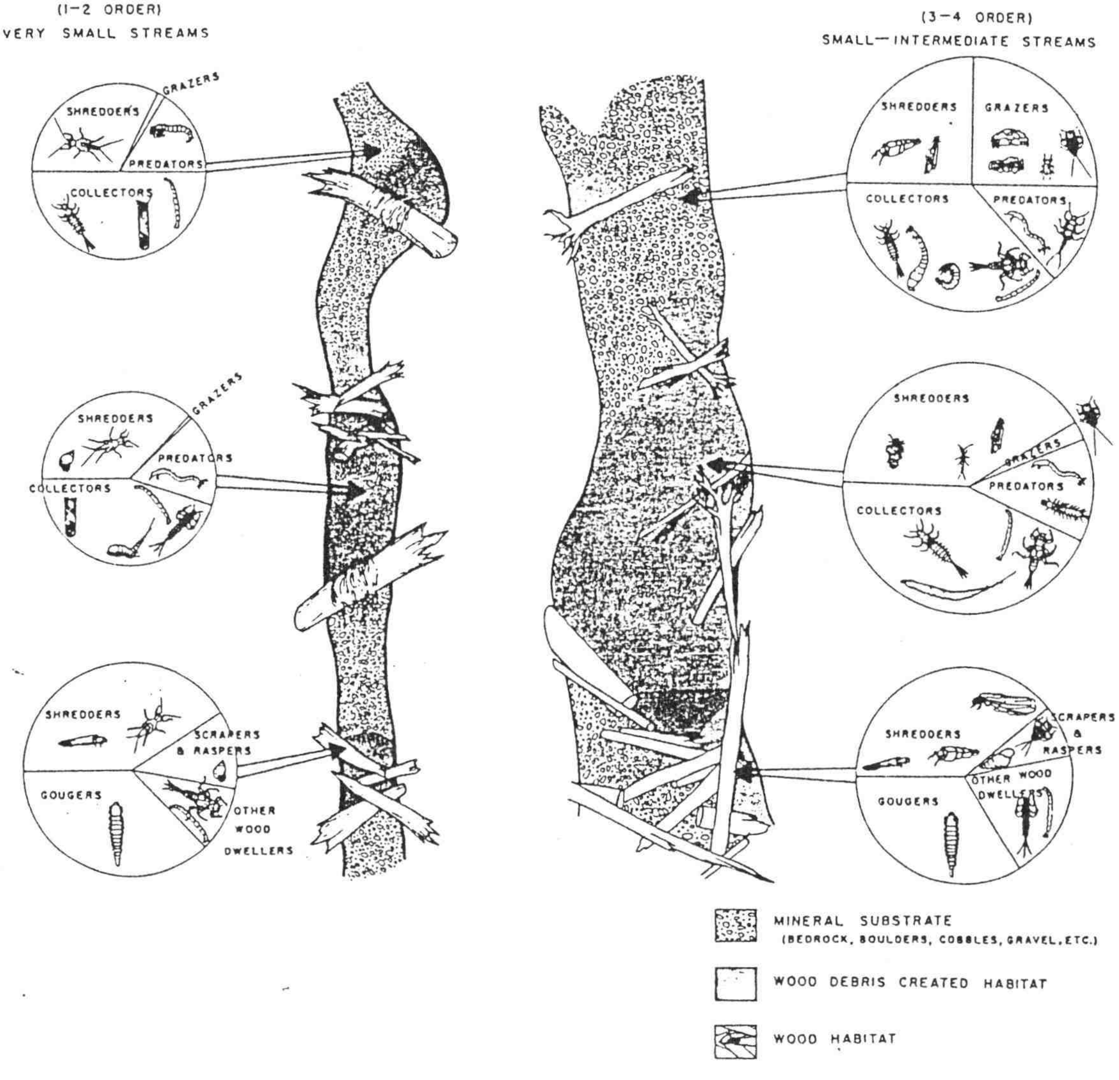


Figure 14. Wood-created micro-habitat diversity and associated invertebrates. From Anderson and Sedell, 1979.

Figure 15. Example of in-channel structure (log weir and pool) in Upper Lobster Creek, Lane Co., OR., 1995.

IN-STREAM STRUCTURES
METHODS

I selected E. Fk. Lobster Cr. as a reference site because no pre-restoration macroinvertebrate data are available for Upper Lobster Cr. To evaluate the effects of restoration on macroinvertebrates, I compared post-restoration conditions in Upper Lobster Cr. to conditions in the unrestored reference, E. Fk. Lobster. Discharge, land use, proximity to roads, topography, and geological character are similar in both Upper and East Fork Lobster Creek, so any differences between the two in macroinvertebrate habitat and communities could be attributed to restoration.

Reach Selection

I conducted extensive physical inventories along the Upper and E. Fk. Lobster to locate study sections that were geomorphically analogous, based on such criteria as stream gradient, adjacent hillslope angle, active channel width, adjacent land use, proximity to roads, percent riparian canopy cover. From these sections, I randomly selected 30-meter study reaches: eight restored reaches on Upper Lobster and eight reference reaches on E. Fk. Lobster. These reaches were similar in terms of gradient (ranging from 2-3%), hillslope angle (12-25°), and canopy cover (60-85%) (Figs. 16-17).

Evaluation of Macroinvertebrate Habitat

I identified macroinvertebrate habitats in each reach according to flow condition and substrate type. Habitats identified included such areas as boulders, riffles over gravel, glides over cobble/gravel, backwater pool/depositional areas, boulders, log- weirs, and log-weir pools. For each reach, the number of different habitats and percent contributed by each habitat was calculated (Appendix 4).

Figure 16. Example of reference (unrestored) reach on East Fork Lobster Creek, Lane Co., OR, 1995.

Figure 17. Example of restored reach on Upper Lobster Creek, Lane Co., OR., 1995. Note construction of a beaver dam above log weir.

Macroinvertebrate Benthos Sampling

Macroinvertebrates were sampled in May and September, 1994, from one reach in each of the two streams. In 1995, the study was expanded and samples were collected from eight reaches in each stream. Samples were collected twice yearly, in May and September. In each reach, samples were taken from all of the macroinvertebrate habitats previously identified using a stratified random sampling scheme. I sampled benthos and boulder habitats with a 0.05 m^2 Hess sampler with 500-micron mesh (Fig. 18). For each log weir, a 0.09 m^2 area was sampled by suspending a 500 micron sieve under the water column while the scrubbing the log immediately above (Fig. 19).

Figure 18. Using Hess Sampler to collect benthic macroinvertebrates. East Fork Lobster Creek, Lane Co., OR., 1995.

Figure 19. Sampling macroinvertebrates from a log weir. Upper Lobster Creek, Lane Co., OR., 1995.

Macroinvertebrates were preserved in 95% ethanol, counted and identified to subfamily (for Chironomidae) and genus when possible (other organisms). Each taxon was assigned to a functional feeding group according to information provided by Merrit and Cummins (1984) and Armitage, et al., (1995) (for chironomids). Macroinvertebrate community diversity was determined using the Shannon-Weaver Index, which incorporates abundance, taxonomic richness, and evenness in a single summary statistic (Washington, 1984).

Macroinvertebrate Drift Sampling

Drift samples were taken from four restored reaches in June, July, August, and September of 1995. Nets were placed at the outlets of log-weir pools, anchored immediately above the weir, to collect drift coming from the pools above. Placement sites across the channel were chosen randomly. When water level in September was insufficient to pour over some weirs, nets were re-positioned to collect drift flowing into "suck holes" forming above them. Forty-eight hour continuous drift samples were taken using $0.0625m^2$ nets with 250 micron mesh. Nets were placed at depths ranging from 12-14 cm. Adequacy of flow through the nets was evaluated using dye. Net contents were emptied when necessary, approximately every 12 hours or less, depending on location and conditions.

Invertebrates and data from a 1991 study of E. Fk. Lobster Cr. drift (Steve Fieth, unpublished data) were used for comparison with 1995 Upper Lobster Cr. drift. The 1991 study had similar flow conditions and used similar methodology. Samples from the 1991 study selected for comparison with the present were randomly chosen from samples taken in habitats matching those of unrestored reaches (i.e., riffles, glides).

Fish Gut Sampling

In early July, 1995, 76 juvenile coho and 84 cutthroat trout (*Oncorhynchus clarki*) were captured from five randomly-selected restored reaches using a backpack electrofisher. Captured fish were immediately placed in a holding bucket and anaesthetized with Finquel^{TM}. Stomach contents were obtained by a non-lethal, mouth-flushing procedure and were preserved in 95% ethanol. After identification to the level of subfamily (for Chironomidae), genus when possible (for other aquatic insects), and order (for terrestrial insects), the stomach contents from all fishes were combined, dried and weighed (Fig. 20).

Figure 20. Extraction of stomach contents from a cutthroat trout using a non-lethal flushing procedure. Upper Lobster Creek, Lane Co., OR., 1995.

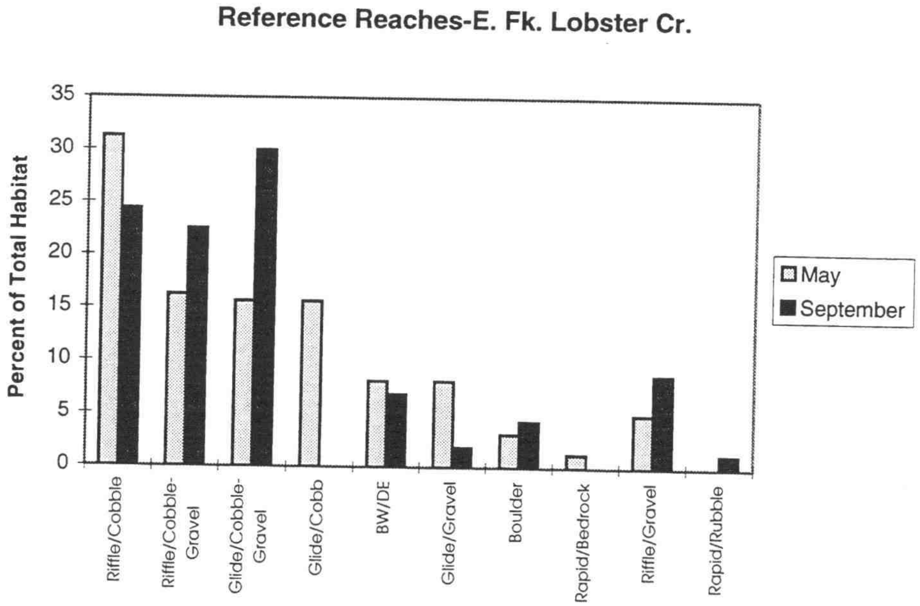
IN-STREAM STRUCTURES
RESULTS

Macroinvertebrate Habitat

Restored and reference streams differed in terms of substrate distribution, flow conditions, and average depth. As a result, they contained different macroinvertebrate habitat assemblages. In both sampling intervals, the number of habitat types observed in restored reaches varied from two to five habitats per reach. Reaches with only two habitats had a log-weir and the pool behind it ("log-weir pool"). Other restored reaches were more complex, containing areas rich with organic deposits, and small riffles and glides. While all reaches contained log-weirs, some weirs were unavailable as macroinvertebrate habitat during periods of low flow, due to undercutting and drying around the weir.

In restored reaches, overall habitat diversity was low due to dominance of log-weir pools which accounted for about 73% of total habitat (Fig. 21). Consequently, average depths throughout the year in restored reaches remained fairly high (0.68 m, +/- 0.15 m) and substrates were homogeneous, comprised primarily of fine particles (silt and sand) under slowly moving or pooled water.

In reference reaches, the number of habitat types varied from two to five per reach. They were dominated by a heterogeneous mixture of relatively coarse substrates (gravel, cobble and rubble) and shallow, moving water (riffles, rapids and glides). Backwater pools and depositional areas were fairly uncommon, contributing only 7-8% of total habitat (Fig. 21). Average depth remained relatively shallow throughout the year (0.24 m).



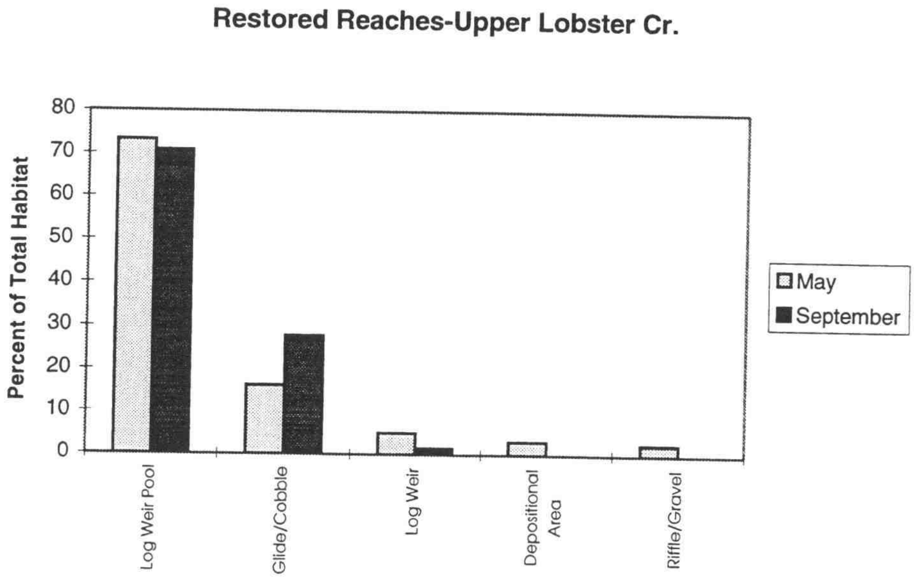


Figure 21. Habitat diversity in reference and restored reaches. East Fork and Upper Lobster Creeks, Lane Co., OR, May and September in 1994 and 1995.

During the fall sampling interval, reduction in water levels and corresponding changes in flow patterns reduced the number of habitat-types in both streams.

Abundance and Diversity of Functional Feeding Groups

Large differences were noted between the two streams in terms of abundance and diversity of functional feeding groups (classification of organisms based on mode of feeding). Restored reaches were dominated by collector-gatherers, which reached an average abundance of 1,782 and 1744 per m^2 in May and September, respectively, and made up 82% of the fauna present (Fig. 22). Of these collector-gatherers, 90-95% were chironomids in log-weir pools.

In the reference stream, mean densities of collector-gatherers reached average abundances of 1,392 and 1,284/m^2 in May and September, respectively, and accounted for 52-60% of total density. However, compared with restored reaches, the collector-gatherer community was more taxonomically diverse. Only 50-52% of all reference streams collector-gatherers were chironomids, while *Baetis* (Baetidae), *Paraleptophlebia* (Leptophlebiidae), and various genera of Ephemerellidae comprised most of the rest. Reference reaches also contained a greater abundance of shredders and scrapers than was found in restored reaches (Fig. 22).

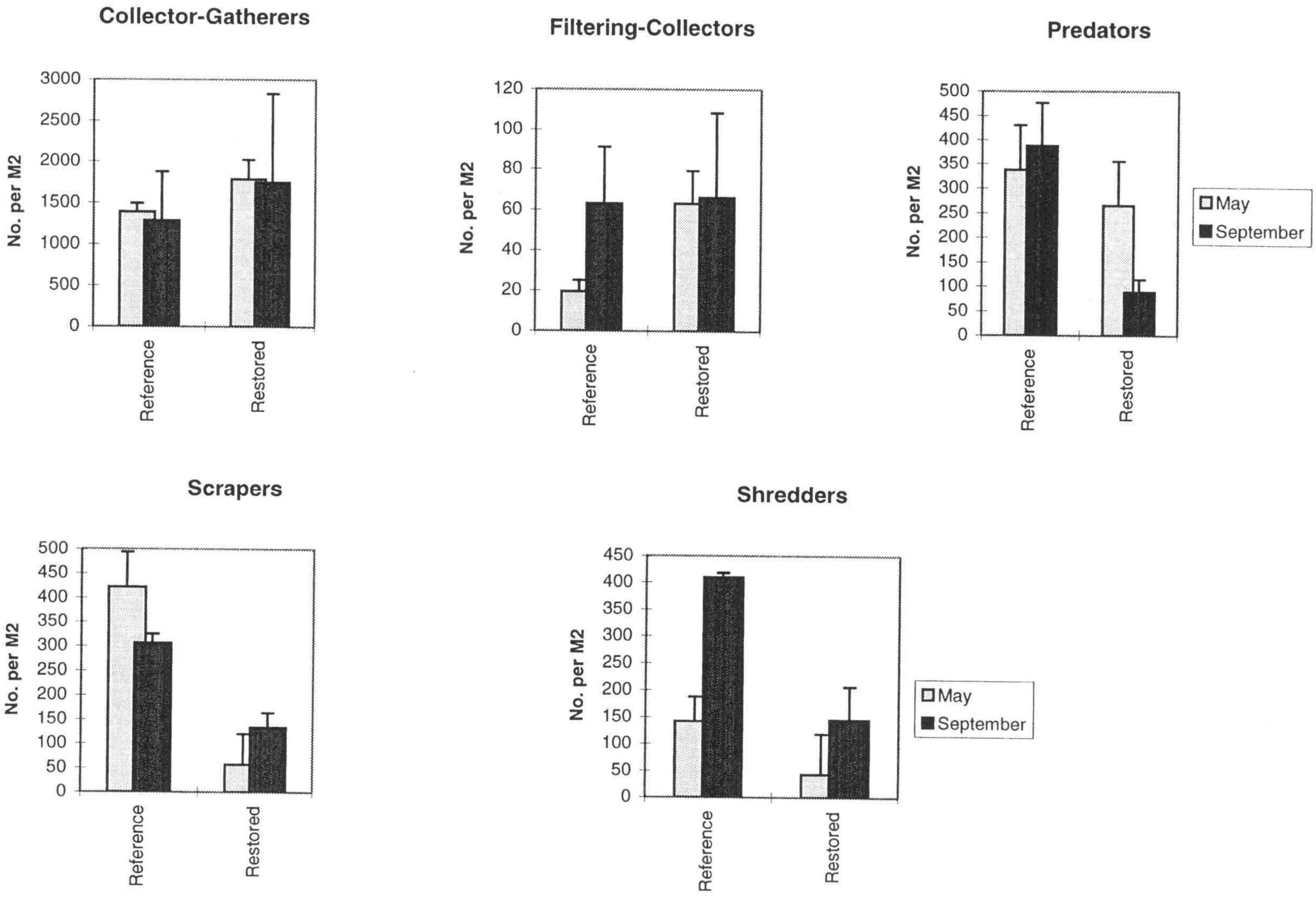


Figure 22. Abundance of various functional feeding groups (+SE) in reference and restored reaches. East Fork and Upper Lobster Creeks, Lane Co., OR., 1994-1995. Values are averages for all reaches.

Richness and Taxonomic Diversity of Macroinvertebrates

The restored stream reaches contained substantially lower generic richness (85 taxa) than did the reference reaches (106 taxa). Chironomids dominated taxonomic diversity in restored reaches, while in reference reaches, richness was distributed more evenly across all genera (Fig. 23). Community diversity, as expressed by the Shannon-Weaver index (ln), was substantially lower in restored reaches (3.45 and 2.88, May and September, respectively) than in reference reaches (5.58 and 5.42, May and September, respectively).

Density of Macroinvertebrates

Abundance (average no/m^2) of invertebrates was not significantly different between the two streams during either sampling period ($p= 0.064$ and 0.378, May and September, respectively; Fig. 24). In both reaches, there was considerable variation in densities among different habitats and among seasons (Fig. 24). In reference reaches, riffles over cobble-gravel contained the highest density, followed by glides over gravel. In restored reaches, the highest abundance was in riffles over gravel, followed by log-weir pools. Average densities on log weirs appeared to relate to the presence or absence of bark. Weirs with bark had 2-3 times more insects than weirs without bark. Average density of benthic invertebrates important in drift and fish diets (see following sections) was significantly higher in reference than in restored reaches (Fig. 25).

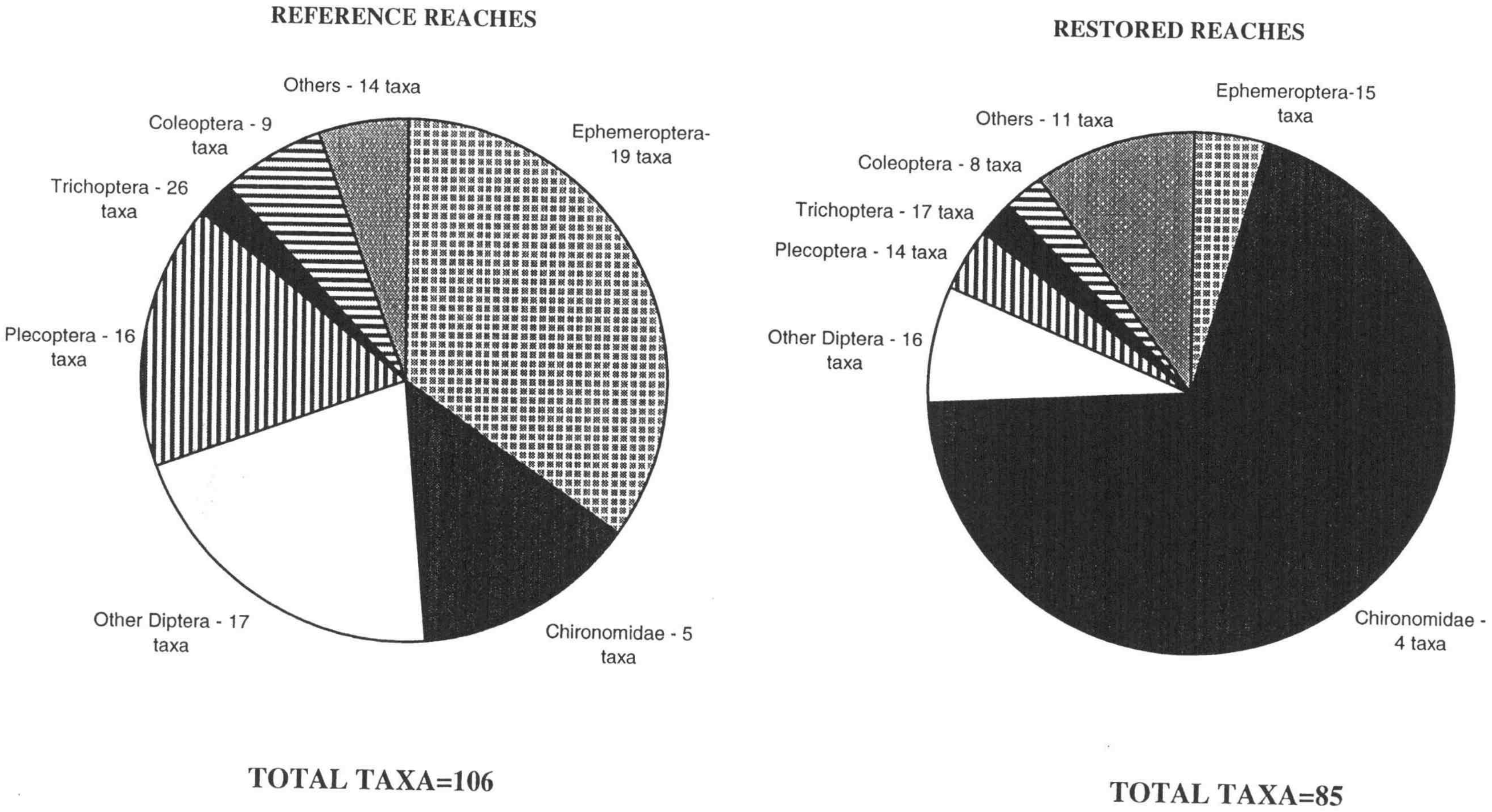


Figure 23. Abundance and richness of major invertebrate orders in reference and restored reaches. Upper and East Fork Lobster Creeks, Lane Co., OR., 1994-1995.

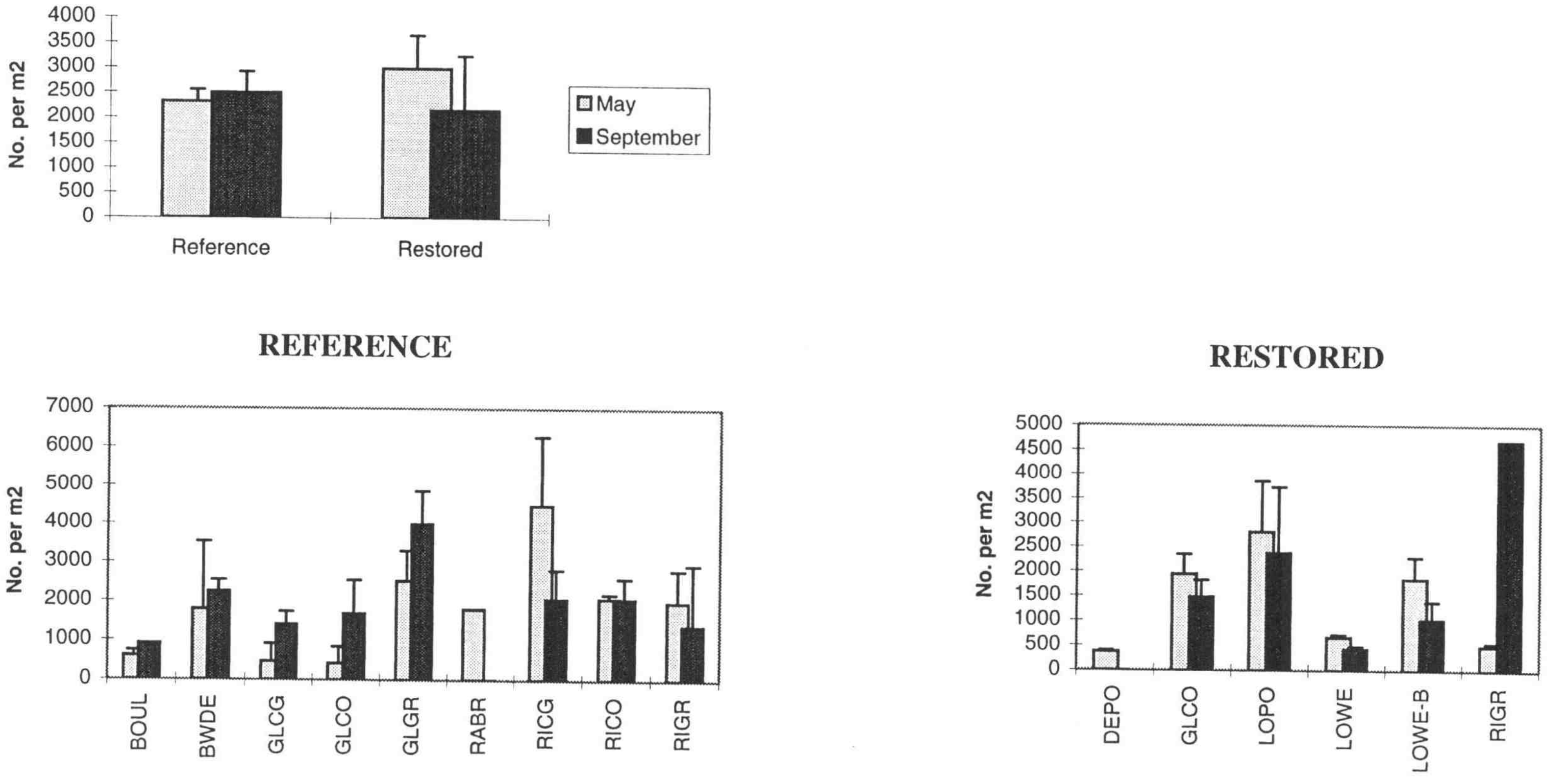


Figure 24. Average density (+SE) of macroinvertebrates in reference and restored reaches. East Fork and Upper Lobster Creeks, 1994-1995. TOP: All habitats combined. BOTTOM: Mean density by habitat. BOUL=boulder, GLCG=glide over cobble-gravel, GLGR=glide over gravel, RICG=riffle over cobble-gravel, RIGR=riffle over gravel, DEPO=depositional area, GLCO=glide over cobble, LOPO=log-weir pool, LOWE=log-weir w/o bark, LOWE-B=log-weir with bark. Habitats without SE had a sample size of 1.

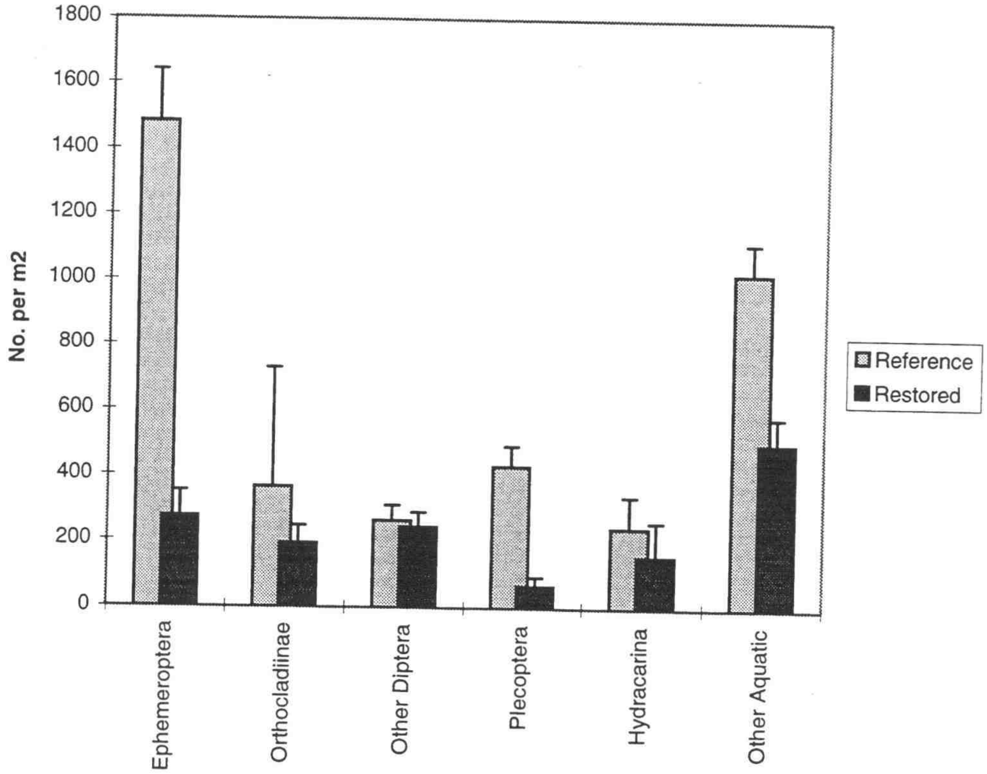


Figure 25. Abundance (+SE) of benthic invertebrates important in drift and fish diets in reference and restored reaches. East Fork and Upper Lobster Creeks, Lane Co., OR., 1994-5. Values are averages for all reaches. Average densities of Ephemeroptera, Orthocladiinae (Chironomidae), Plecoptera and Other Aquatic are significantly higher in reference reaches (respectively, $p=0.0002$, 0.035, 0.0001 and 0.0002).

Macroinvertebrate Drift

I observed substantial differences in drift abundance between restored and reference reaches. After accounting for differences in net sizes, average number of organisms drifting per hour/m^2 (of water column) in reference reaches ranged from 1,023 to 17,422 and averaged 6,923 (SE 1334). Drift abundance in restored reaches ranged from 2 to 1,121 organisms/hour and averaged only 32 (SE 10.21) organisms/hour/m^2. Composition of drift, however, was not substantially different between the two streams. Ephemeroptera, Chironomidae (Orthocladiinae), and other Diptera taxa comprised approximately 75% of drift in both areas. Tanytarsini chironomids contributed less than 1% of drift in restored areas, and 9% in unrestored reaches. Proportions of terrestrial organisms and Hydracarina were significantly different between the two (Fig. 26).

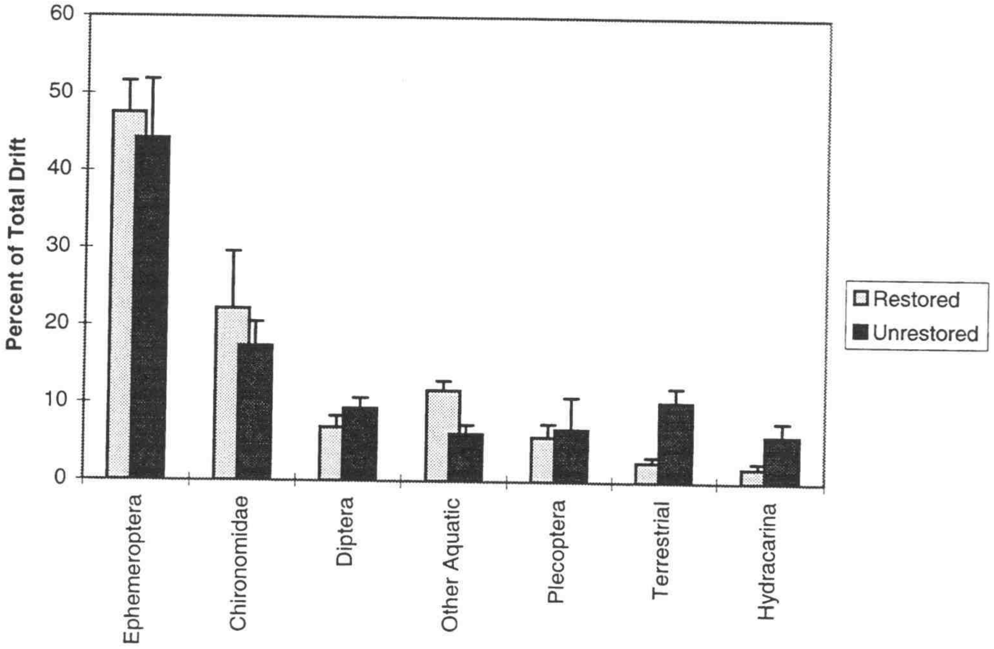


Figure 26. Drift composition (+SE) in restored and unrestored reaches. East Fork and Upper Lobster Creeks, Lane Co., OR. Data from restored reaches are from 1995; unrestored data are from 1991,courtesy of S. Fieth. Percentages of Ephemeroptera, Chironomidae, Diptera, and Plecoptera are not significantly different (p=0.73, 0.489, 0.361, 0.892, respectively). Percentages of Other Aquatic, Terrestrial and Hydracarina are significantly different (p=0.023 , 0.015 and 0.035, respectively).

Fish Diet Analysis

Diets of fish in restored areas were composed primarily of terrestrial invertebrates and aquatic organisms produced in habitats that are characteristic of unrestored areas (i.e., riffles and glides over coarse substrates). The composition of diet closely resembled that of drift. Orthocladiinae (Chironomidae) were most abundant followed by Ephemeroptera (*Baetis, Serratella*), terrestrial organisms (Hymenoptera, beetle larvae, mycetophilid flies), and other aquatic Diptera (primarily Dixidae: *Dixa*) (Fig. 27). By weight, Chironomids accounted for a very small proportion fish diets (1.10 mg) as opposed to terrestrial organisms and mayflies, which contributed 8.60 gr.

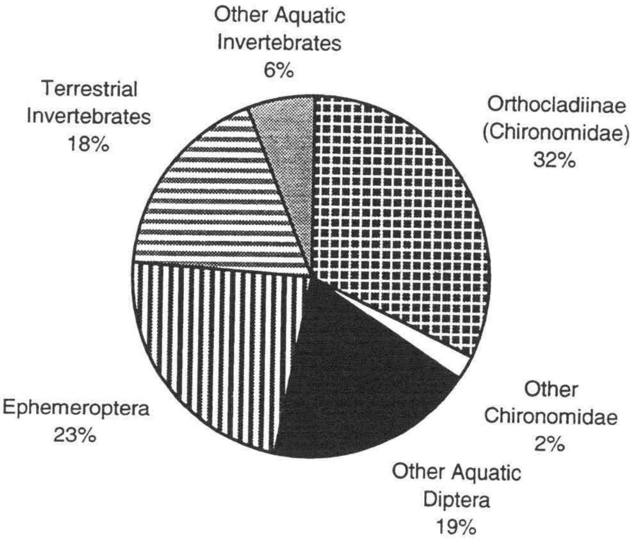


Figure 27. Composition by of fish diets in restored reaches. Upper Lobster Creek, Lane Co., OR. Data are from July, 1995, and are based on numerical abundance of taxa in diets of coho salmon and cutthroat trout (sample size: 589 invertebrates).

IN-CHANNEL STRUCTURES
DISCUSSION

Benthic macroinvertebrate habitat is created through the interaction of stream hydraulics and substrates. The nature and diversity of available habitat subsequently influences the size and composition of macroinvertebrate communities (Minshall and Rabeni 1977, Statzner and Higler 1986). Results from my study indicate that in-channel fish habitat structures substantially reduced the abundance of macroinvertebrate habitats in Upper Lobster Creek. Although the reference stream reaches did not contain habitat that would be considered adequate from a fisheries standpoint (that is, having numerous, complex pools), a mosaic of hydraulic patterns and substrates in reference reaches created a varied assortment of macroinvertebrate habitat-types. In contrast, the placement of channel-spanning weirs in restored reaches has created large pools, but eliminated most of the hydraulic and substrate complexity important for macroinvertebrate communities.

Greater taxonomic and functional feeding-group diversity in reference reaches was likely due to diverse and abundant habitat-types and to the predominance of cobble habitats. These typically have diverse macroinvertebrate communities because cobble provides heterogeneous micro-sites for insect attachment and refuge (Ward, 1992) as well as permiting a wide variety of niches to exist. For example, organic material may fall out into the interstices between particles, providing fine particulate organic matter (FPOM) for the collector-gatherer guild; cobbles also provide relatively stable substrate, allowing algal growth for scrapers and stability for filter-feedinginvertebrates. In E. Fk. Lobster Cr., cobble habitats contained the highest macroinvertebrate densities and taxonomic diversity.

Low taxonomic diversity in restored reaches was due not only to habitat simplification, but to the fact that the dominant habitat (deep pools with fine substrates) is unsuitable for many macroinvertebrate taxa and functional feeding groups. In log weir-pools, filter-feeding is ineffective because of insufficient current and low light, and unsuitable substrates prevent the algal growth necessary to support scrapers. Microbial respiration in accumulated organic sediments may create l ow oxygen concentrations at the sediment-water interface (Ward 1992, Pinder 1995). Furthermore, the undifferentiated silt bottom provides fewer refuges from fish and invertebrate predators. As a result, log-weir pools are dominated by one ecological guild (collector-gatherer FPOM feeders), and Tanytarsini chironomids as the single taxon.

Tube-building chironomids, such as Tanytarsini, are adapted to survive in conditions provided by log-weir pools. Tubes provide refuge from predators, which accounts for heavier predation losses of free-living chironomids (Armitage et al. 1995). Tubes also allow chironomids to live a few millimeters above anoxic sediments as well as allow for specialized respiration movements (Elliott 1971, Pinder 1995); as a result, these chironomids are able to thrive in low-oxygen areas.

The data showed differences in drift patterns between reaches in restored Upper Lobster and unrestored E. Fk. Lobster. Drift abundance was signficantly lower in restored areas than in unrestored areas. This difference may be due to variation in invertebrate production between 1991 and 1995. Drift abundances observed in restored reaches, however, were also substantially lower than abundances commonly reported in the literature (Mundie 1974, Allan 1978, Wilzbach et al. 1989), including two studies that used the same nets (Anderson 1966, Reed 1995).

Low drift abundances observed in restored reaches may be due to a combination of factors. First, invertebrates drifting into the log-weir pool from upstream may fall out of drift in the extensive pool; as a result, they may not reach drift nets. This explanation is consistent with the findings of Waters (1962) and Smith and Li (1983), who reported significant reductions in drift density in areas with low water velocities. Secondly, drift passing through log-weir pools could have been intercepted by fish before it reached the nets. Data from the Oregon Department of Fish and Wildlife showed high densities of fish in the log weir pools when the study was conducted (S. Johnson, pers. comm.). Finally, low drift densities recorded from log-weir pools may be because these pools are producing primarily tube-building Tanytarsini chironomids. I would argue that organisms such as Tanytarsines, that invest time and energy to build an immobile retreat, are less likely than free-living or portable tube-building forms to abandon that retreat and to enter drift. My data, showing that Tanytarsini chironomids composed a very small fraction of the total drift in both reaches (<1% and 8%, restored and reference reaches, respectively) are consistent with this argument.

Regardless of the underlying mechanism(s), low drift densities at outlets of log-weir pools restrict the supply of drift to downstream fishes, especially if another log weir exists immediately downstream with insufficient invertebrate production in between to replenish drift. This is consistant with the findings of J. and H. Li (unpublished data) of Oregon State University, who reported food limitation for fish residing in downstream sections of a series of a log weir pools.

Although *abundances* of drift were lower in restored reaches than in unrestored reaches, the *composition* of the drift was similar in both streams. Drift in both streams was primarily invertebrates produced in riffles and glides over coarse substrates (cobbles), or terrestrial insects (caterpillars, beetle larvae, winged adults). Correspondingly, fishes residing in restored reaches relied heavily on invertebrates produced outside of restored areas for food. The relative abundance of terrestrial organisms in the diets of fishes in restored reaches demonstrates that riparian vegetation provides much more than shade and structure to aquatic biota.

The effects of restoration observed in this study were localized, and restricted only to that section of stream affected by the installation of a restoration structure. Furthermore, the effects of restoration assessed here relate to the creation of log-weir pools in a relatively gravel-rich stream. A similar restoration project performed on a bedrock stream would be expected to yield different results.

IN-STREAM STRUCTURES
CONCLUSIONS

Habitat quantity (i.e., number of pools) and quality (amount of cover) are often considered as the primary factors limiting survival and production of fishes in Coast Range streams. However, food abundance is also a factor determining carrying capacity for fish. The supply of incoming drift-food can increase the carrying capacity of pools (Mason and Chapman 1965, Peterson 1966), and may override cover in determining fish abundance in summer months (Murphy and Meehan 1991). Results from this study indicate that in-channel restoration alters stream ecosystems in a manner that has potential implications for fish production, especially in streams where high temperature increases metabolism in fishes and, subsequently, increases their food requirements. In Upper Lobster Cr., fishes feeding in restored areas relied primarily on invertebrates produced in unrestored areas. In-channel structures eliminated the habitats that produced most drifting organisms. Log-weir pools primarily produced Tanytarsini chironomids that contributed little to drift and that may avoid epi-benthic fish predation through tube-building. Low drift abundance in log-weir pools, whether from the falling-out of drift, from predation, or from insufficient production of drifting organisms, restricts the supply of drift-food to downstream fish. As a result, these in-channel structures may not only affect macroinvertebrates, but the fishes that the structures were trying to help in the first place.

PART III

GENERAL DISCUSSION AND RECOMMENDATIONS FOR MANAGEMENT

The dominant habitat created by both in- and off-channel restoration is the pool, so it is interesting to note the differences in macroinvertebrate communities between them. Average macroinvertebrate density in the benthos of artificial alcoves (approx. 4,500/m^2) is considerably higher than in log-weir pools (approx. 2,600/m^2). This is unexpected because habitat conditions in artificial alcoves (large depths over anoxic organic sediments) appear much less favorable than the comparatively benign conditions in the benthos of log-weir pools. I speculate that higher benthic densities recorded from artificial alcoves are the result of differences in sampling efficiency between two sampling methods. The hand-pump used in alcoves created a relatively powerful suction, the while the Hess sampler used in log-weir pools used less powerful, hand-created currents to move insects and sediments through the net. Average densities of benthos invertebrates in log-weir pools are probably much higher than observed in this study.

The supposition that better habitat conditions exist for macroinvertebrates within the benthos of log-weir pools than in artificial alcoves is supported by differences between the two in community diversity and in dominant taxa. Benthic community diversity in log-weir pools is more than twice that of alcove pools. While taxa in the benthos of both pool types were dominated by Chironomidae, the dominant chironomid taxon in each was different. Tanytarsini was most numerous in the benthos of log-weir pools, whereas Chironomini (predominately *Chironomus)* was clearly dominant in artificial alcoves.

Both chironomid taxa are adapted to life in habitats with low oxygen levels, but Chironomini, particularly the genus *Chironomus*, are known to be most tolerant of severe anoxic conditions (Armitage et al. 1995).

Neither type of restoration structure effectively mimics the hydrologic function or the relative density and distribution of the natural stream features that they were intended to enhance or replace. For example, within the Lobster Cr. system, most natural pools (which log-weir pools attempt to imitate) are small, transient features, that move and change with stream hydraulics. In the unrestored E. Fk. Lobster Cr., pool habitats may be numerous within a reach but are relatively small and rarely span the channel. In contrast, log-weir pools are large, created by permanently-anchored structures that limit hydrological complexity and simplify stream habitats where they are installed. Likewise, artificial alcoves are large, permanent structures. They are installed in narrow valleys where alcoves would normally not exist and are thus removed from the hydrologic inputs of the floodplain water table and the stream channel. In contrast, natural alcoves are small, dynamic features which change with stream hydraulics, and are located exclusively in areas where floodplain water tables and streamflow provide hydrologic inputs.

Macroinvertebrate habitats and communities are affected very differently by the two types of fish-habitat structures. Artificial alcoves increase macroinvertebrate habitat diversity within a reach because they are constructed in off-channel areas and create habitats that are absent from or were not originally present in the reach. Conversely, in the reaches where log weirs are installed, the log-weir pools eliminate existing habitats, which decreases macroinvertebrate habitat and community diversity, as well as reduces production of drifting organisms and the abundance of drift.

It is important to note that the effects of in-channel structures on macroinvertebrate habitat and communities observed in this study are restricted to the reaches where those structures are installed. Log-weir pools in Upper Lobster Cr., while large in scale, are found in low numbers, are well-spaced, and have not substantially affected macroinvertebrate habitat or communities on a drainage level. However, when in-stream structures are installed close together in large scale projects (Fig. 28), they have the potential not only to affect macroinvertebrate communities, but the survival of the fish who rely on those macroinvertebrates for food.

The ultimate effect of fish habitat restoration on macroinvertebrate communities depends on the initial condition of the stream (i.e., bedrock-dominated vs. gravel-rich), and on the scale (size of structures), and intensity (number of structures) with which these projects are applied. Furthermore, while structures such as artificial alcoves increase macroinvertebrate habitat and community diversity where they were constructed, I question the wisdom of installing off-channel structures in narrow valleys where such habitats probably never existed naturally and where the adjacent stream channels cannot support them. Thus, if stream restoration is to be successful, installed structures should closely imitate the hydrologic function, density and distribution across the landscape of the habitats that they attempt to replace/enhance. The most successful stream restoration, for macroinvertebrates, fishes, and other aquatic organisms will attempt to restore whole-system integrity instead of targeting just fish.

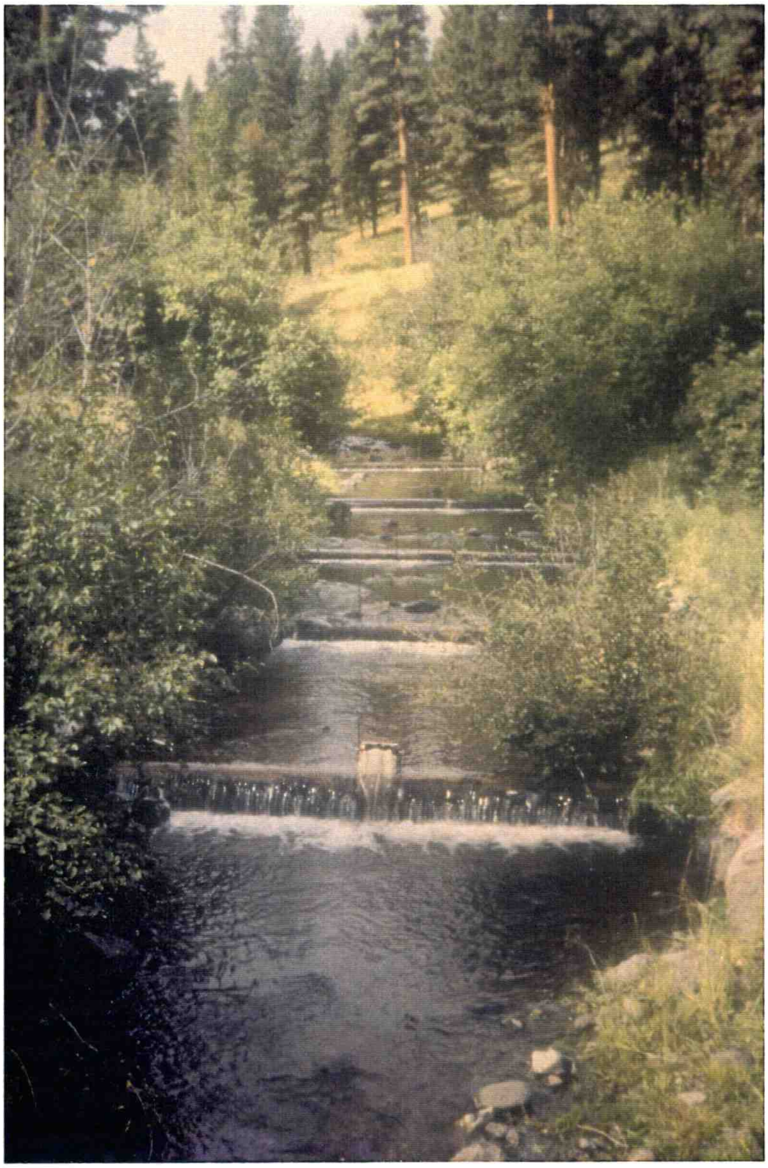


Figure 28. Example of long series of closely spaced log-weir pools. Photograph of Camp Creek in Eastern Oregon is courtesy of H. Li, Oregon State University.

RECOMMENDATIONS FOR MANAGEMENT

1) Before restoration planning and implementation, fishery managers should survey the availability of macroinvertebrate habitats. If habitats important for macroinvertebrate abundance, biodiversity, and production of drift are limited in proposed areas, then structures should be installed in a manner that avoids eliminating them.

2) The design of installed structures should mimic the hydrologic complexity of the natural features they intend to imitate. Bark should be retained on logs to be installed in streams.

3) This study highlighted the relative importance of terrestrial insects in the diets of fishes in restored areas. Disturbance to terrestrial vegetation should be minimized during installation of fish habitat structures.

4) Long series of log-weir pools should not be created without sufficient space between them to retain the riffle habitats that are important for supplying food to fish in those pools.

5) Restoration should work towards restoring whole-system integrity and function, instead of targeting just fish.

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APPENDICES

APPENDIX I

ABUNDANCE BY HABITAT OF TAXA IN ARTIFICIAL AND NATURAL ALCOVES

Numbers are based on average densities/meter^2 from all sample intervals and alcoves of each type combined.

BANK

	ORDER (or other taxon)	FAMILY (or other taxon)	GENUS (or other taxon)	No/m^2 Artificial	No/m^2 Natural
INSECTA	EPHEMEROPTERA	Baetidae	*Callibaetis*	9	0
		Baetidae	Unknown	7	0
		Ephemerellidae	*Drunella*	4	0
		Heptageniidae	*Cinygma*	0	4
		Leptophlebiidae	*Paraleptophlebia*	12	4
		Siphlonuridae	*Siphlonurus*	16	0
		Unknown	Unknown	8	0
	Totals			48	8
	ODONATA	Aeshnidae	*Aeshna*	5	0
		Aeshnidae	*Anax*	4	0
		Coenagrionidae	*Argia*	16	0
		Coenagrionidae	Unknown	4	8
		Coenagrionidae	*Zoniagrion*	21	0
		Gomphidae	*Octogomphus*	8	4
		Libellulidae	Unknown	8	0
	Totals			75	12
	PLECOPTERA	Leuctridae	*Moselia*	4	0
		Leuctridae	Unknown	0	4
		Nemouridae	*Malenka*	12	0
		Unknown	Unknown	4	0
	Totals			20	4
	HEMIPTERA	Corixidae	*Corisella*	80	0
		Corixidae	*Hesperocorixa*	4	0
		Gerridae	*Gerris*	8	4
		Gerridae	*Limnoporus*	4	0
		Nepidae	*Ranatra*	56	0
		Veliidae	*Microvelia*	14	0
	Totals			166	4
	MEGALOPTERA	Sialidae	*Sialis*	4	0

BANK, continued

ORDER (or other taxon)	**FAMILY** (or other taxon)	**GENUS** (or other taxon)	**No/m^2 Artificial**	**No/m^2 Natural**
TRICHOPTERA	Hydroptilidae	*Hydroptila*	4	0
	Lepidostomatidae	*Lepidostoma*	43	22
	Limnephilidae	*Asynarchus*	33	0
	Limnephilidae	*Dicosmoecus*	4	16
	Limnephilidae	*Halesochila taylori*	32	0
	Limnephilidae	*Homophylax*	16	0
	Limnephilidae	*Limnephilus*	28	0
	Limnephilidae	*Onocosmoecus unicolor*	26	24
	Limnephilidae	*Psychoglypha*	4	0
	Limnephilidae	*Unknown*	8	4
	Phryganeidae	*Ptilostomis*	16	0
Totals			258	66
COLEOPTERA	Dytiscidae	*Agabus*	49	7
	Dytiscidae	*Hydaticus*	56	0
	Dytiscidae	*Hydroporus*	36	0
	Dytiscidae	*Hydrovatus*	16	0
	Dytiscidae	*Oreodytes*	8	0
	Dytiscidae	*Sanfilippodytes*	4	32
	Dytiscidae	*Uvarus*	8	0
	Dytiscidae	Unknown	27	10
	Elmidae	*Zaitzevia*	4	0
	Gyrinidae	*Gyrinus*	28	0
	Hydrophilidae	Unknown	0	16
Totals			236	65
DIPTERA-NEMATOCERA	Ceratopogonidae	*Culicoidinae*	398	35
	Chaoboridae	*Mochlonyx*	8	0
	Chironomidae	Chironomini	423	848
	Chironomidae	Orthocladinae	268	4
	Chironomidae	Tanypodinae	121	32
	Chironomidae	Tanytarsini	156	6
	Chironomidae	Unknown	771	53
	Culicidae	*Culex*	0	4
	Dixidae	*Dixa*	4	0
	Dixidae	*Dixella*	36	14
	Dixidae	*Meringodixa*	0	8
	Simuliidae	*Simulium*	8	0
	Tipulidae	*Limonia*	32	0
	Tipulidae	*Pilaria*	0	12
	Tipulidae	Unknown	16	8
	Unknown	Unknown	16	0

BANK, continued

	ORDER (or other taxon)	**FAMILY** (or other taxon)	**GENUS** (or other taxon)	**No/m^2** **Artificial**	**No/m^2** **Natural**
	DIPTERA-BRACHYCERA	Empididae	*Clinocera*	8	0
		Stratiomyiidae	Unknown	8	8
		Tabanidae	*Chrysops*	68	0
		Tabanidae	Unknown	4	8
		Unknown (Orthorhapha)	Unknown	8	0
		Unknown (pupae)	Unknown	195	86
	Totals			2548	1125
GASTROPODA	PROSOBRANCHIA	Pleuroceridae	*Juga*	31	92
BIVALVIA	PELECYPODA	Sphaeriidae	*Pisidium*	39	141
HYDRACHNIDA	UNKNOWN	Unknown	Unknown	41	8
EUMALACOSTRACA	ISOPODA	Unknown	Unknown	0	8
BRANCHIOPODA	CLADOCERA	Daphniidae	Unknown	16	0
		Unknown	Unknown	32	0
	Totals			48	0
COPEPODA	COPEPODA	Unknown	Unknown	40	0

BENTHOS

	ORDER (or other taxon)	**FAMILY** (or other taxon)	**GENUS** (or other taxon)	**No/m^2 Artificial**	**No/m^2 Natural**
INSECTA	EPHEMEROPTERA	Baetidae	*Callibaetis*	144	0
		Ephemerellidae	*Serratella*	0	16
		Leptophlebiidae	*Paraleptophlebia*	32	0
	Totals			176	16
	ODONATA	Aeshnidae	*Aeshna*	32	0
		Gomphidae	*Octogomphus*	128	18
		Libellulidae	Unknown	0	4
	Totals			160	22
	PLECOPTERA	Nemouridae	*Malenka*	0	8
	Totals			0	8
	MEGALOPTERA	Sialidae	*Sialis*	152	0
	TRICHOPTERA	Hydroptilidae	*Hydroptila*	64	0
		Lepidostomatidae	*Lepidostoma*	0	26
		Limnephilidae	*Asynarchus*	48	32
		Limnephilidae	*Dicosmoecus*	0	4
		Limnephilidae	*Halesochila taylori*	253	0
		Limnephilidae	*Hydatophylax*	0	4
		Limnephilidae	*Limnephilus*	32	0
		Limnephilidae	*Onocosmoecus*	0	9
		Limnephilidae	*Pseudostenophylax edwardsi*	32	0
		Limnephilidae	*Psychoglypha*	4	4
		Uenoidae	*Neophylax*	0	4
	Totals			433	83
	COLEOPTERA	Dytiscidae	*Agabus*	12	14
		Dytiscidae	*Hydaticus*	16	12
		Dytiscidae	*Oreodytes*	32	0
		Dytiscidae	*Uvarus*	0	32
		Dytiscidae	*Unknown*	32	34
		Elmidae	*Heterlimnius*	0	4
		Elmidae	*Narpus*	0	16
		Elmidae	*Optioservus*	0	8
	Totals			92	120
	DIPTERA-NEMATOCERA	Ceratopogonidae	Culicoidinae	276	111
		Chironomidae	Chironomini	1567	1397
		Chironomidae	Orthocladinae	142	74
		Chironomidae	Prodiamesinae	0	16
		Chironomidae	Tanypodinae	1408	406
		Chironomidae	Tanytarsini	48	64
		Chironomidae	Unknown	4488	2489

BENTHOS, continued

	ORDER (or other taxon)	**FAMILY** (or other taxon)	**GENUS** (or other taxon)	**No/m^2 Artificial**	**No/m^2 Natural**
	DIPTERA-NEMATOCERA, continued	Culicidae	*Culista*	0	278
		Diptera	Unknown	87	53
		Dixidae	*Dixella*	16	0
		Ptychopteridae	*Bittacomorpha*	0	32
		Ptychopteridae	*Ptychoptera*	0	269
		Tipulidae	*Antocha*	320	0
		Tipulidae	*Unknown*	0	18
	DIPTERA-BRACHYCERA	Stratiomyiidae	*Allognosta*	0	4
		Tabanidae	*Chrysops*	64	0
		Tabanidae	Unknown	160	16
		Unknown-Orthorrhapha	Unknown	0	10
	Totals			8577	5237
GASTROPODA	PROSOBRANCHIA	Pleuroceridae	*Juga*	77	465
		Hydrobiidae	*Fontelicella*	0	16
		Hydrobiidae	*Gyralus*	0	4
		Hydrobiidae	Unknown	0	4
		Planorbiidae	Unknown	16	16
	Totals			93	505
BIVALVIA	PELECYPODA	Sphaeriidae	*Pisidium*	352	2191
HYDRACHNIDA	UNKNOWN	Unknown	Unknown	170	35
COPEPODA	UNKNOWN	Unknown	Unknown	69	32

DEPOSITIONAL AREA

	ORDER (or other taxon)	**FAMILY** (or other taxon)	**GENUS** (or other taxon)	**No/m^2 Artificial**	**No/m^2 Natural**
INSECTA	EPHEMEROPTERA	Baetidae	*Baetis*	22	18
		Baetidae	*Unknown*	36	4
		Ephemerellidae	*Attenella*	0	4
		Ephemerellidae	*Ephemerella*	12	24
		Ephemerellidae	*Serratella*	0	8
		Ephemerellidae	*Unknown*	24	0
		Heptageniidae	*Cinygmula*	0	16
		Heptageniidae	*Epeorus*	0	12
		Leptophlebiidae	*Leptophlebia*	0	12
		Leptophlebiidae	*Paraleptophlebia*	27	40
		Leptophlebiidae	*Unknown*	19	0
		Siphlonuridae	*Ameletus*	32	12
		Unknown	Unknown	0	28
	Totals			171	178
	ODONATA	Gomphidae	*Octogomphus*	44	33
		Libellulidae	Unknown	0	16
	Totals			44	49
	PLECOPTERA	Chloroperlidae	Unknown	0	12
		Nemouridae	*Malenka*	16	76
		Perlodidae	Unknown	0	34
		Unknown	Unknown	0	18
	Totals			16	140
	MEGALOPTERA	Sialidae	*Sialis*	48	0
	TRICHOPTERA	Hydroptilidae	*Orthotrichia*	800	0
		Lepidostomatidae	*Lepidostoma*	24	27
		Leptoceridae	*Unknown*	0	8
		Limnephilidae	*Dicosmoecus*	12	12
		Limnephilidae	*Homophylax*	0	8
		Limnephilidae	*Limnephilus*	32	0
		Limnephilidae	*Onocosmoecus*	32	10
		Limnephilidae	*Psychoglypha*	93	12
		Limnephilidae	*Unknown*	0	11
		Rhyacophilidae	*Rhyacophila*	0	17
		Uenoidae	*Neophylax*	8	6
	Totals			1001	111

DEPOSITIONAL AREA, continued

	ORDER (or other taxon)	**FAMILY** (or other taxon)	**GENUS** (or other taxon)	**No/m^2 Artificial**	**No/m^2 Natural**
	COLEOPTERA	Dytiscidae	*Hydrovatus*	16	0
		Dytiscidae	*Liodessus*	16	0
		Dytiscidae	*Oreodytes*	15	20
		Dytiscidae	*Unknown*	0	4
		Dytiscidae	*Uvarus*	4	0
		Elmidae	*Heterlimnius*	6	0
		Elmidae	*Optioservus*	0	16
		Elmidae	Unknown	0	112
		Hydrophilidae	Unknown	16	0
		Unknown	Unknown	64	0
	Totals			138	152
	DIPTERA-NEMATOCERA	Ceratopogonidae	Culicoidinae	1151	148
		Chironomidae	Chironomini	547	236
		Chironomidae	Orthocladinae	64	66
		Chironomidae	Tanypodinae	83	36
		Chironomidae	Tanytarsini	16	0
		Chironomidae	Unknown	2056	617
		Dixidae	*Dixella*	16	0
		Empididae	*Clinocera*	0	4
		Psychodidae	*Pericoma*	504	0
		Ptychopteridae	*Bittacomorpha*	32	0
		Ptychopteridae	*Ptychoptera*	12	23
		Simuliidae	*Simulium*	8	0
		Simuliidae	Unknown	16	0
		Tipulidae	*Antocha*	64	0
		Tipulidae	*Hexatoma*	5	4
		Tipulidae	*Pilaria*	0	32
		Tipulidae	Unknown	0	24
		Unknown	Unknown	165	75
	DIPTERA-BRACHYCERA	Stratiomyiidae	Unknown	64	0
		Tabanidae	*Chrysops*	32	4
		Tabanidae	Unknown	48	48
		Unknown-Orthorrhapha	Unknown	32	0
	Totals			4916	1317
GASTROPODA	PROSOBRANCHIA	Pleuroceridae	*Juga*	232	215
		Hydrobiidae	*Fluminicola*	0	16
	Totals			232	231
BIVALVIA	PELECYPODA	Sphaeriidae	*Pisidium*	358	672
HYDRACHNIDA	Unknown	Unknown	Unknown	83	16
COPEPODA	Unknown	Unknown	Unknown	12	16

WOOD

	ORDER	FAMILY (or other taxon)	GENUS (or other taxon)	No/m^2 Artificial	No/m^2 Natural
INSECTA	ODONATA	Aeshnidae	*Aeshna*	0	22
	PLECOPTERA	Nemouridae	*Malenka*	0	67
	TRICHOPTERA	Brachycentridae	*Micrasema*	0	89
		Lepidostomatidae	*Lepidostoma*	33	56
		Limnephilidae	*Asynarchus*	22	0
		Limnephilidae	*Halesochila taylori*	0	22
		Limnephilidae	*Limnephilus*	0	22
		Limnephilidae	*Onocosmoecus unicolor*	22	22
		Limnephilidae	Unknown	22	0
	Totals			99	211
	COLEOPTERA	Dytiscidae	*Agabus*	22	0
		Dytiscidae	*Sanfilippodytes*	0	22
		Dytiscidae	Unknown	45	22
		Elmidae	*Lara*	0	22
		Elmidae	Unknown	22	22
		Unknown1	Unknown	22	0
		Unknown2	Unknown	0	22
	Totals			111	110
	DIPTERA-NEMATOCERA	Ceratopogonidae	Culicoidinae	458	133
		Chaoboridae	*Mochlonyx*	22	0
		Chironomidae	Chironomini	401	2606
		Chironomidae	Orthocladinae	1269	0
		Chironomidae	Tanypodinae	59	490
		Chironomidae	Tanytarsini	33	0
		Chironomidae	Unknown	876	783
		Dixidae	*Dixa*	0	22
		Dixidae	*Dixella*	22	0
		Muscidae	Unknown	22	0
		Ptychopteridae	*Ptychoptera*	0	134
		Tipulidae	*Antocha*	0	89
		Tipulidae	*Pilaria*	0	56
		Tipulidae	Unknown	0	22
	DIPTERA-BRACHYCERA	Muscidae	Unknown	22	0
		Unknown	Unknown	120	29
	Totals			3304	4364
GASTROPODA	Prosobranchia	Pleuroceridae	*Juga*	0	45
BIVALVIA	Pelecypoda	Sphaeriidae	*Pisidium*	89	196
HYDRACHNIDA	Unknown	Unknown	Unknown	46	78

RIFFLE OUTFLOW

	ORDER (or other taxon)	**FAMILY** (or other taxon)	**GENUS** (or other taxaon	**No/m^2 Artificial**
INSECTA	EPHEMEROPTERA	Heptageniidae	*Cinygma*	4
		Leptophlebiidae	*Leptophlebia*	16
		Leptophlebiidae	*Paraleptophlebia*	126
	Totals			146
	ODONATA	Gomphidae	*Octogomphus*	4
	PLECOPTERA	Nemouridae	*Malenka*	1742
	HEMIPTERA	Veliidae	*Microvelia*	6
	TRICHOPTERA	Lepidostomatidae	*Lepidostoma*	13
		Limnephilidae	*Asynarchus*	16
		Limnephilidae	*Onocosmoecus*	4
		Limnephilidae	*Pseudostenophylax*	48
		Limnephilidae	*Psychoglypha*	24
		Rhyacophilidae	*Rhyacophila*	8
		Uenoidae.	*Neophylax*	2064
	Totals			2177
	COLEOPTERA	Dytiscidae	*Agabus*	96
		Dytiscidae	*Oreodytes*	10
		Dytiscidae	*Sanfilippodytes*	4
		Dytiscidae	Unknown	16
		Elmidae	*Optioservus*	6
		Elmidae	Unknown	16
	Totals			148
	DIPTERA-NEMATOCERA	Ceratopogonidae	Culicoidinae	319
		Chironomidae	Chironomini	200
		Chironomidae	Orthocladinae	384
		Chironomidae	Tanypodinae	80
		Chironomidae	Unknown	3216
		Unknown Nematocera	Unknown	231
		Ptychopteridae	*Ptychoptera*	72
		Simuliidae	*Prosimulium*	48
		Tipulidae	*Limnophila*	4
		Tipulidae	*Pilaria*	16
		Tipulidae	Unknown	208
		Simuliidae	Unknown	16
	DIPTERA-BRACHYCERA	Empididae	*Clinocera*	64
		Tabanidae	*Chrysops*	4
	Totals			4862

RIFFLE OUTFLOW, continued

	ORDER (or other taxon)	**FAMILY** (or other taxon)	**GENUS** (or other taxaon	**No/m^2 Artificial**
GASTROPODA	PROSOBRANCHIA	Pleuroceridae	*Juga*	302
BIVALVIA	PELECYPODA	Sphaeriidae	*Pisidium*	424
HYDRACHNIDA	UNKNOWN	Unknown		239
	OSTRACODA	Ostracoda	Unknown	4
COPEPODA	CLADOCERA	Copepoda	Copepoda	16

APPENDIX II

ABUNDANCE BY HABITAT OF MACROINVERTEBRATE TAXA OF EAST FORK LOBSTER CREEK

Numbers are based on average densities/meter^2 from all habitat-types and sample intervals combined.

	Order (or other taxon)	**Family** (or other taxon)	**Genus** (or other taxon)	**BOUL**	**BWDE**	**GLCG**	**GLCO**	**GLGR**	**RABR**	**RARU**	**RICG**	**RICO**	**RIGR**	**TOTALS**
INSECTA	EPHEMEROPTERA	Baetidae	*Baetis*	270	391	130	235	225	900	80	668	402	224	3235
		Ephemerellidae	*Attenella*	0	0	160	0	280	0	0	680	0	0	1120
			Caudatella	20	33	40	0	27	20	0	26.7	30	30	227
			Drunella	20	0	60	25	20	100	0	60	50	0	335
			Ephemerella	100	100	60	0	40	40	0	70	0	0	410
			Eurylophella	0	20	40	0	40	0	0	60	0	80	240
			Serratella	60	174	68	40	173	140	20	190	160	356	1381
			Timpanoga	20	20	50	40	30	0	0	40	0	0	200
		Heptageniidae	*Cinygma*	0	20	0	53.33	0	0	0	0	0	0	73
			Cinygmula	20	0	99	720	141	0	0	311	157	225	1668
			Epeorus	20	58	40	68	73	0	40	144	187	80	710
			Ironodes	30	0	0	0	0	0	20	20	27	0	97
			Rithrogena	30	20	0	0	70	0	0	227	316	40	703
			Unknown	0	40	0	0	0	0	0	0	0	40	80
		Leptophlebiidae	*Paraleptophlebia bicornuta*	0	0	20	0	67	0	0	120	0	60	267
			Paraleptophlebia	0	1028	50	260	236	20	0	160	103	311	2168
		Siphlonuridae	*Ameletus*	0	15	20	20	245	0	0	47	30	80	457
			Siphlonurus	0	20	0	0	80	0	0	0	100	0	200
			TOTALS	590	1939	837	1461	1737	1220	160	2829	1562	1562	13861

APPENDIX II, continued

Abundance of Taxa in East Fork Lobster Creek

Order (or other taxon)	**Family** (or other taxon)	**Genus** (or other taxon)	**BOUL**	**BWDE**	**GLCG**	**GLCO**	**GLGR**	**RABR**	**RARU**	**RICG**	**RICO**	**RIGR**	**TOTALS**
ODONATA	Aeshnidae	*Aeshna*	0	10	0	0	0	0	0	0	0	0	10
	Gomphidae	*Octogomphus*	0	6.3	20	20	50	0	0	40	60	33	229
		TOTALS	0	16	20	20	50	0	0	40	60	33	239
PLECOPTERA	Chloroperlidae	Unknown	0	0	0	0	40	0	0	0	0	0	40
		Haploperla	0	1072	76	93	110	0	0	130	60	40	1581
		Kathroperla	0	0	0	0	0	0	0	80	0	240	320
		Sweltsa	0	25	0	80	90	0	0	0	60	0	255
	Leuctridae	*Leuctridae*	0	7	30	80	70	0	0	80	40	53	360
	Nemouridae	*Malenka*	0	266	50	50	80	0	40	270	48	148	952
		Zapada	20	0	60	200	80	0	0	173	60	580	1173
		Unknown	0	80	0	0	0	0	0	0	0	0	80
	Peltoperlidae	Unknown	0	0	0	0	0	20	0	0	0	0	20
	Perlidae	*Calineuria*	0	0	25	30	0	0	0	0	20	40	115
		Doroneuria	0	0	20	0	0	0	0	0	0	0	20
		Hesperoperla	0	0	40	0	0	0	0	80	0	100	220
	Perlodidae	*Frisonia*	0	20	0	0	0	0	0	0	0	0	20
		Isoperla	0	80	40	20	47	0	0	120	20	100	427
		Skwala	0	110	64	60	104	0	20	87	55	55	555
		Unknown	0	210	0	20	0	0	0	0	60	40	330
	Pteronarcyidae	*Pteronarcella*	0	20	0	0	0	0	0	0	0	0	20
	Unknown	Unknown	0	0	0	0	20	0	0	0	0	0	20
		TOTALS	20	1890	405	633	641	20	60	1020	423	1396	6508
MEGALOPTERA	Sialidae	*Sialis*	0	7	40	0	0	0	0	40	0	0	87

APPENDIX II, continued

Abundance of Taxa in East Fork Lobster Creek

Order (or other taxon)	**Family** (or other taxon)	**Genus** (or other taxon)	BOUL	BWDE	GLCG	GLCO	GLGR	RABR	RARU	RICG	RICO	RIGR	TOTALS
TRICHOPTERA	Brachycentridae	*Micrasema*	148	53	140	60	80	0	40	167	47	150	885
	Calamoceratidae	*Heteroplectron*	0	10	0	0	0	0	0	0	0	0	10
	Glossosomatidae	*Glossosoma*	0	0	40	20	0	0	0	40	33	0	133
	Hydropsychidae	*Hydropsyche*	0	0	73	0	0	0	0	240	80	0	393
	Hydropsychidae	*Parapsyche*	0	0	0	20	0	0	20	80	20	0	140
	Hydroptilidae	*Hydroptila*	0	227	240	60	0	0	0	0	20	620	1167
	Hydroptilidae	*Orthotrichia*	0	140	40	0	0	0	0	0	0	20	200
	Hydroptilidae	Unknown	0	0	0	0	0	0	0	0	0	20	20
	Lepidostomatidae	*Lepidostoma cascadense*	0	28	0	20	50	0	0	0	0	0	98
	Lepidostomatidae	*Lepidostoma*	0	1720	70	32	248	0	0	60	30	20	2180
	Lepidostomatidae	*Lepidostoma unicolor*	0	59	20	0	0	0	0	0	0	20	99
	Limnephilidae	*Apatania*	60	20	20	0	65	0	80	153	80	105	583
	Limnephilidae	*Dicosmoecus*	0	0	50	50	20	0	0	60	0	20	200
	Limnephilidae	*Hydatophylax hesperus*	0	45	20	0	0	0	0	0	0	0	65
	Limnephilidae	*Limnephilidae*	0	0	0	60	100	0	0	0	0	0	160
	Limnephilidae	*Limnephilus*	0	60	0	0	0	0	0	0	0	0	60
	Limnephilidae	*Onocosmoecus unicolor*	0	20	0	20	20	0	0	0	0	0	60
	Limnephilidae	*Pseudostenophylax edwardsi*	0	0	0	0	30	0	0	60	0	0	90
	Limnephilidae	*Psychoglypha*	0	413	60	0	80	0	0	0	0	0	553
	Polycentropodidae	*Polycentropus*	0	0	0	50	0	0	0	0	0	0	50
	Psychomyiidae	*Psychomyiia*	0	0	40	20	0	0	0	100	20	20	200

APPENDIX II, continued

Abundance of Taxa in East Fork Lobster Creek

Order (or other taxon)	**Family** (or other taxon)	**Genus** (or other taxon)	**BOUL**	**BWDE**	**GLCG**	**GLCO**	**GLGR**	**RABR**	**RARU**	**RICG**	**RICO**	**RIGR**	**TOTALS**
	Rhyacophilidae	*Himalopsyche phryganea*	0	20	0	0	0	0	0	0	20	0	40
	Rhyacophilidae	*Rhyacophila sp 1*	20	81.7	44	45	33	0	40	90	42.5	107	503
	Rhyacophilidae	*Rhyacophila sp 2*	0	0	0	0	0	0	0	0	0	50	50
	Uenoidae	*Neophylax*	0	0	130	80	220	60	0	0	40	20	550
	Unknown	Unknown	0	70	40	60	20	0	0	20	0	20	230
		TOTALS	228	2967	1027	597	966	60	180	1070	433	1192	8719
COLEOPTERA	Dytiscidae	Unknown	0	20	0	0	0	0	0	0	0	0	20
	Elmidae	*Dubiraphia*	0	0	0	0	40	0	0	40	0	0	80
	Elmidae	*Elmidae*	0	71	77	64	73	0	0	64	44	277	670
	Elmidae	*Heterlimnius*	0	340	27	40	315	0	0	20	47	40	829
	Elmidae	*Lara*	0	553	0	20	0	0	0	0	0	0	573
	Elmidae	*Narpus*	0	0	0	0	20	0	0	60	40	0	120
	Elmidae	*Optioservus*	0	0	80	30	80	0	0	20	70	140	420
	Elmidae	*Zaitzevia*	0	2	40	47	80	0	0	50	40	27	286
	Hydrophilidae	Unknown	0	5	0	20	0	0	0	0	0	20	45
		TOTALS	0	991	224	221	608	0	0	254	241	504	3043

APPENDIX II, continued

Abundance of Taxa in East Fork Lobster Creek

Order (or other taxon)	**Family** (or other taxon)	**Genus** (or other taxon)	BOUL	BWDE	GLCG	GLCO	GLGR	RABR	RARU	RICG	RICO	RIGR	TOTALS
DIPTERA-NEMATOCERA	Ceratopogonidae	Culicoidinae	0	47.8	20	60	40	0	0	0	0	73	241
	Chironomidae	Unknown	140	3800	184	280	597	0	0	255	296	529	6081
	Chironomidae	Chironomini	0	124	213	105	73	0	0	93	96	40	744
	Chironomidae	Orthocladinae	53	167	147	380	160	440	80	700	257	97	2481
	Chironomidae	Podonominae	0	0	0	0	0	0	0	0	0	20	20
	Chironomidae	Tanypodinae	20	88	48	20	70	39	0	90	20	155	550
	Chironomidae	Tanytarsini	40	262	130	112	368	0	40	136	80	393	1561
	Pelecorhynchidae	*Glutops*	0	60	0	40	60	0	0	0	20	0	180
	Psychodidae	*Pericoma*	0	20	0	60	40	0	0	0	60	110	290
	Ptychopteridae	*Ptychoptera*	0	308	0	20	0	0	0	0	0	0	328
	Simuliidae	*Twinnia*	0	0	0	0	0	0	0	80	0	0	80
	Simuliidae	*Prosimulium*	0	0	0	0	20	0	0	140	40	40	240
	Simuliidae	Pupae	0	0	0	0	0	0	0	0	20	0	20
	Simuliidae	Unknown	0	0	0	0	20	0	0	0	90	0	110
	Stratiomyiidae	*Nemoletus*	0	0	0	0	0	0	0	0	0	20	20
	Tipulidae	*Antocha*	20	29	40	500	50	0	0	40	60	27	806
	Tipulidae	*Dicranota*	20	53	20	50	35	0	0	40	30	50	298
	Tipulidae	*Hexatoma*	0	10	20	0	20	0	0	0	0	20	70
	Tipulidae	*Holorusia*	0	10	0	0	0	0	0	0	0	0	10
	Tipulidae	*Limonia*	0	10	0	0	20	0	0	0	0	60	90
	Tipulidae	*Tipula*	0	0	20	0	20	0	0	0	0	50	90
	Tipulidae	Unknown	0	5	0	20	20	0	0	0	0	0	45
	Unknown-pupae	Unknown	60	250	190	93	60	0	0	240	75	170	1138

APPENDIX II, continued

Abundance of Taxa in East Fork Lobster Creek

	Order (or other taxon)	**Family** (or other taxon)	**Genus** (or other taxon)	**BOUL**	**BWDE**	**GLCG**	**GLCO**	**GLGR**	**RABR**	**RARU**	**RICG**	**RICO**	**RIGR**	**TOTALS**
	DIPTERA-BRACHYCERA	Empididae	*Chelifera*	0	0	0	400	0	0	0	0	0	20	420
		Tabanidae	*Chrysops*	0	40	0	0	0	0	0	0	0	100	140
		Unknown-Orthorrhapha	Unknown	0	0	0	0	0	0	0	20	0	20	40
			TOTALS	353	5304	1032	2140	1713	479	120	1834	1144	1994	16113
GASTROPODA	PROSOBRANCHIA	Hydrobiidae	*Hespericola*	0	0	20	0	33	0	0	0	0	50	103
		Hydrobiidae	Unknown	0	0	0	20	0	0	0	0	0	0	20
		Pleuroceridae	*Juga*	10	1	9	0	4	10	2	1	2	0	39
			TOTALS	20	20	60	20	93	0	0	0	20	50	322
MALACOSTRACA	AMPHIPODA	Gammaridae	Gammaridae	0	0	0	0	0	0	0	0	0	60	60
HYDRACHNIDA	UNKNOWN	Unknown	Unknown	20	177	330	100	204	20	0	47	30	475	1403
COPEPODA	UNKNOWN	Unknown	Unknown	0	2	0	20	0	0	0	0	0	0	20

BOUL=Boulder, BWDE=Backwater pool/Depositional rea, GLCG=Glide over cobble-gravel, GLCO=Glide over cobble, GLGR=Glide over gravel, RABR=Rapid over bedrock, RARU=Rapid over rubble, RICG=Riffle over cobble-gravel, RIGR=Riffle over gravel.

APPENDIX III

ABUNDANCE BY HABITAT OF TAXA IN UPPER LOBSTER CREEK

Numbers are based on average densities/meter^2 from all habitat-types and sample intervals combined.

	ORDER (or other taxon)	**Family** (or other taxon)	**Genus** (or other taxon)	**BOUL**	**DEPO**	**GLCO**	**LOPO**	**LOWE**	**PLPO**	**RIGR**	**TOTALS**
INSECTA	EPHEMEROPTERA	Baetidae	*Baetis*	0	0	124	45	370	120	147	806
		Ephemerellidae	*Attenella*	0	0	0	0	4	0	0	4
			Caudatella	0	0	20	0	70	0	0	90
			Drunella	0	0	0	0	18	0	0	18
			Eurylophella	0	0	60	91.25	15	60	0	226
			Serratella	0	0	64	20	179	0	0	263
			Timpanoga	0	0	20	20	0	0	20	60
		Heptageniidae	*Cinygmula*	0	0	93	20	0	20	100	233
			Epeorus	0	0	136	0	13	80	40	269
			Ironodes	0	0	0	0	49	0	0	49
			Rithrogena	0	0	0	0	73	0	160	133
			Unknown	0	0	0	0	0	60	0	60
		Leptophlebiidae	*Paraleptophlebia*	0	22	134	47	37	100	1247	1587
		Siphlonuridae	*Ameletus*	0	0	30	60	0	0	0	90
			TOTALS	0	22	681	303	828	440	1714	3988
	ODONATA	Gomphidae	*Octogomphus*	0	15	40	26	0	30	0	111

APPENDIX III, continued

Abundance of Taxa in Upper Lobster Creek

ORDER (or other taxon)	**Family** (or other taxon)	**Genus** (or other taxon)	**BOUL**	**DEPO**	**GLCO**	**LOPO**	**LOWE**	**PLPO**	**RIGR**	**TOTALS**
PLECOPTERA	Chloroperlidae	*Haploperla*	0	0	58	0	11	100	0	169
		Sweltsa	0	0	40	0	0	0	0	40
		Unknown 1	0	0	0	0	39	0	40	79
		Unknown 2	0	0	0	0	22	0	0	22
	Leuctridae	Unknown	0	5	27	0	0	0	0	32
	Nemouridae	*Malenka*	0	10	104	20	53	0	20	207
		Zapada	0	0	540	20	24	20	120	724
	Peltoperlidae	*Yoraperla*	0	0	0	0	4	0	0	4
	Peltoperlidae	Unknown	0	0	0	0	16	0	0	16
	Perlidae	*Calineuria*	0	0	0	0	0	0	40	40
		Hesperoperla	0	0	0	0	0	0	60	60
		Unknown	20	0	0	0	0	0	0	20
	Perlodidae	*Isoperla*	0	10	20	0	4	0	0	34
		Skwala	0	5	80	20	13	0	40	158
		TOTALS	20	30	869	60	186	120	320	1605
MEGALOPTERA	Sialidae	*Sialis*	0	0	20	20	0	0	0	40

APPENDIX III, continued

Abundance of Taxa in Upper Lobster Creek

ORDER (or other taxon)	**Family** (or other taxon)	**Genus** (or other taxon)	**BOUL**	**DEPO**	**GLCO**	**LOPO**	**LOWE**	**PLPO**	**RIGR**	**TOTALS**
TRICHOPTERA	Brachycentridae	*Micrasema*	0	0	20	20	128	0	20	188
	Glossosomatidae	*Glossosoma*	0	0	0	0	0	0	20	20
	Hydropsychidae	*Hydropsyche*	0	0	0	0	11	0	40	51
		Parapsyche	0	0	0	0	11	0	0	11
		Unknown	0	0	0	0	45	40	0	85
	Hydroptilidae	*Hydroptila*	0	0	20	130	0	0	0	150
	Hydroptilidae	*Orthotrichia*	0	0	0	90	0	0	0	90
	Lepidostomatidae	*Lepidostoma cascadense*	0	30	0	0	0	0	0	30
		Lepidostoma unicolor	0	30	0	0	0	0	0	30
		Lepidostoma	0	25	130	137	11	1020	0	1323
	Limnephilidae	*Apatania*	0	0	40	10	0	0	0	50
		Dicosmoecus	0	0	110	0	0	0	0	110
		Hydatophylax hesperus	0	12	0	0	11	20	0	43
		Onocosmoecus unicolor	0	0	30	0	11	0	0	41
		Psychoglypha	0	27	0	43	0	0	0	70
	Rhyacophilidae	*Rhyacophila*	0	0	49	20	11	20	60	160
	Uenoidae	*Neophylax*	80	0	30	0	0	20	0	130
	Unknown	Unknown	0	15	0	0	0	0	0	15
		TOTALS	80	139	429	450	239	1120	140	2597

APPENDIX III, continued

Abundance of Taxa in Upper Lobster Creek

ORDER (or other taxon)	**Family** (or other taxon)	**Genus** (or other taxon)	**BOUL**	**DEPO**	**GLCO**	**LOPO**	**LOWE**	**PLPO**	**RIGR**	**TOTALS**
COLEOPTERA	Dytiscidae	Unknown	0	0	0	0	0	20	0	20
	Elmidae	*Heterlimnius*	0	17	49	50	33	720	40	909
		Narpus	0	0	20	0	0	0	0	20
		Optioservus	0	0	57	35	88	60	100	340
		Stenelmis	0	20	0	20	0	0	0	40
		Zaitzevia	0	0	33	0	0	0	0	33
		Unknown	0	13	193	94	33	0	0	333
	Hydraenidae	*Hydraena*	0	0	0	0	4	0	0	4
	Hydrophilidae	Unknown	0	5	0	0	0	0	0	5
		TOTALS	0	55	352	199	158	800	140	1905
COPEPODA	Unknown	Unknown	0	40	0	40	0	0	0	80
DIPTERA-Nematocera										
	Athericidae	*Atherix*	0	0	0	0	33	0	0	33
	Ceratopogonidae	Culicoidinae	0	22	20	74	0	0	0	116
	Chironomidae	Chironomini	0	5	53	19	22	0	0	99
	Chironomidae	Orthocladiinae	0	42	158	90	884	0	0	1174
	Chironomidae	Tanypodinae	0	0	44	0	120	103	0	267
	Chironomidae	Tanytarsini	0	143	412	1474	33	0	0	2062
	Chironomidae	Unknown	0	121	197	927	182	220	20	1667
	Dixidae	*Dixa*	0	0	0	0	4	0	0	4
	Dixidae	*Dixella*	0	0	0	0	12	0	0	12
	Dixidae	*Meringodixa*	0	0	0	20	0	0	0	20
	Empididae	*Chelifera*	0	5	20	0	22	0	0	47

APPENDIX III, continued

Abundance of Taxa in Upper Lobster Creek

	ORDER (or other taxon)	**Family** (or other taxon)	**Genus** (or other taxon)	**BOUL**	**DEPO**	**GLCO**	**LOPO**	**LOWE**	**PLPO**	**RIGR**	**TOTALS**
	DIPTERA-Nematocera continued	Pelecorhynchidae	*Glutops*	0	0	0	28	0	0	0	28
		Psychodidae	*Pericoma*	0	0	90	131	0	120	0	341
		Ptychopteridae	*Ptychoptera*	0	10	20	20	0	0	0	50
		Simuliidae	*Prosimulium*	0	0	20	0	62	0	0	82
		Simuliidae	Unknown	20	0	0	0	250	20	0	290
		Tipulidae	*Antocha*	0	0	0	50	0	0	20	70
		Tipulidae	*Dicranota*	0	0	30	20	0	0	0	50
		Tipulidae	*Limonia*	0	0	20	0	0	0	0	20
		Tipulidae	*Pilaria*	0	0	0	5	0	0	0	5
		Tipulidae	*Tipula*	0	0	0	40	0	0	0	40
		Tipulidae	Unknown	0	0	0	0	11	0	0	11
		Unknown-pupae	Unknown	0	5	110	410	51	0	0	576
	DIPTERA-Brachycera	Tabanidae	*Chrysops*	0	5	20	40	11	0	0	76
			TOTALS	20	353	1194	3308	1686	463	40	7064
GASTROPODA	PROSOBRANCHIA	Pleuroceridae	*Juga*	510	13	96	70	20	280	87	1076
BIVALVIA	PELECYPODA	Sphaeriidae	*Pisidium*	0	10	40	133.8	0	0	0	183
HYDRACHNIDA	UNKNOWN	Unknown	Unknown	0	52	100	229	15	40	0	436
MALACOSTRACA	AMPHIPODA	Gammaridae	Unknown	0	0	20	0	0	0	0	20

APPENDIX III, continued

Abundance of Taxa in Upper Lobster Creek

BOUL=boulder, DEPO=depositional area, GLCO=glide over cobble, LOPO=log-weir pool, LOWE=log weir, PLPO=plunge pool, RIGR=riffle over gravel

APPENDIX IV

PROPORTIONS OF VARIOUS MACROINVERTEBRATE HABITAT-TYPES IN REFERENCE AND RESTORED REACHES, 1994-1995

Upper and East Forks Lobster Creek, Lane Co., OR. 1994-1995

	REFERENCE		RESTORED	
REACH NO.	HABITATS-TYPES	PERCENT OF TOTAL HABITAT	HABITAT-TYPES	PERCENT OF TOTAL HABITAT
		MAY, 1994		
1	Boulder	10	Log-weir	5
	Riffle over cobble	25	Log-weir pool	85
	Riffle over cobble-gravel	15	Glide over cobble	5
	Glide over cobble-gravel	35	Rapid over rubble	3
	Backwater Pool/ Depositional Area	15	Riffle over gravel	2
		SEPTEMBER, 1994		
1	Boulder	5	Log-weir	2
	Riffle over gravel	20	Log weir pool	95
	Glide over cobble-gravel	55	Glide over cobble	3
	Glide over gravel	15		
	Backwater Pool/ Depositional Area	5		
		MAY, 1995		
1	Backwater Pool/Depositional Area	15	Log-weir	5
	Rapid over bedrock	10	Log-weir pool	50
	Riffle over cobble-gravel	10	Glide over cobble	40
	Glide over cobble-gravel	65	Depositional area	5
2	Riffle over cobble-gravel	90	Log-weir	5
	Glide over gravel	5	Log-weir pool	95
	Backwater Pool/Depositional Area	5		
3	Riffle over cobble-gravel	30	Log-weir	5
	Glide over cobble-gravel	60	Log-weir pool	50
	Backwater Pool/Depositional Area	10	Glide over cobble	45

APPENDIX IV, continued

PROPORTIONS OF VARIOUS HABITAT-TYPES

REFERENCE			RESTORED	
REACH NO.	HABITATS-TYPES	PERCENT OF TOTAL HABITAT	HABITAT-TYPES	PERCENT OF TOTAL HABITAT
4	Riffle over cobble	60	Log-weir	5
	Glide over gravel	10	Log-weir pool	80
	Boulder	10	Glide over cobble	10
	Backwater Pool/ Depositional Area	20	Depositional area	5
5	Boulder	20	Log-weir	5
	Riffle ver cobble/gravel	65	Log-weir Pool	95
	Rapid over rubble	10		
	Glide over gravel	5		
6	Riffle over cobble	40	Log-weir	5
	Riffle over gravel	5	Log-weir pool	95
	Glide over gravel	10		
	Glide over cobble	45		
7	Riffle over cobble	50	Log-weir	5
	Glide over cobble-gravel	30	Log-weir pool	85
	Glide over gravel	15	Depositional area	5
	Backwater Pool/ Depositional Area	5	Glide over cobble-rubble	5
8	Glide over cobble	40	Log-weir	5
	Riffle over cobble	50	Log-weir pool	95
	Riffle over gravel	5		
	Glide over gravel	5		
		SEPTEMBER, 1995		
1	Glide over cobble-gravel	25	Log-weir-sidecut	0
	Riffle over cobble-gravel	45	Log-weir pool	60
	Backwater Pool/ Depositional Area	15	Glide over cobble	40
	Glide over gravel	15		
2	Glide over cobble-gravel	30	Log-weir	2
	Riffle over gravel	35	Log-weir pool	58
	Backwater Pool/ Depositional Area	35	Glide over cobble	40

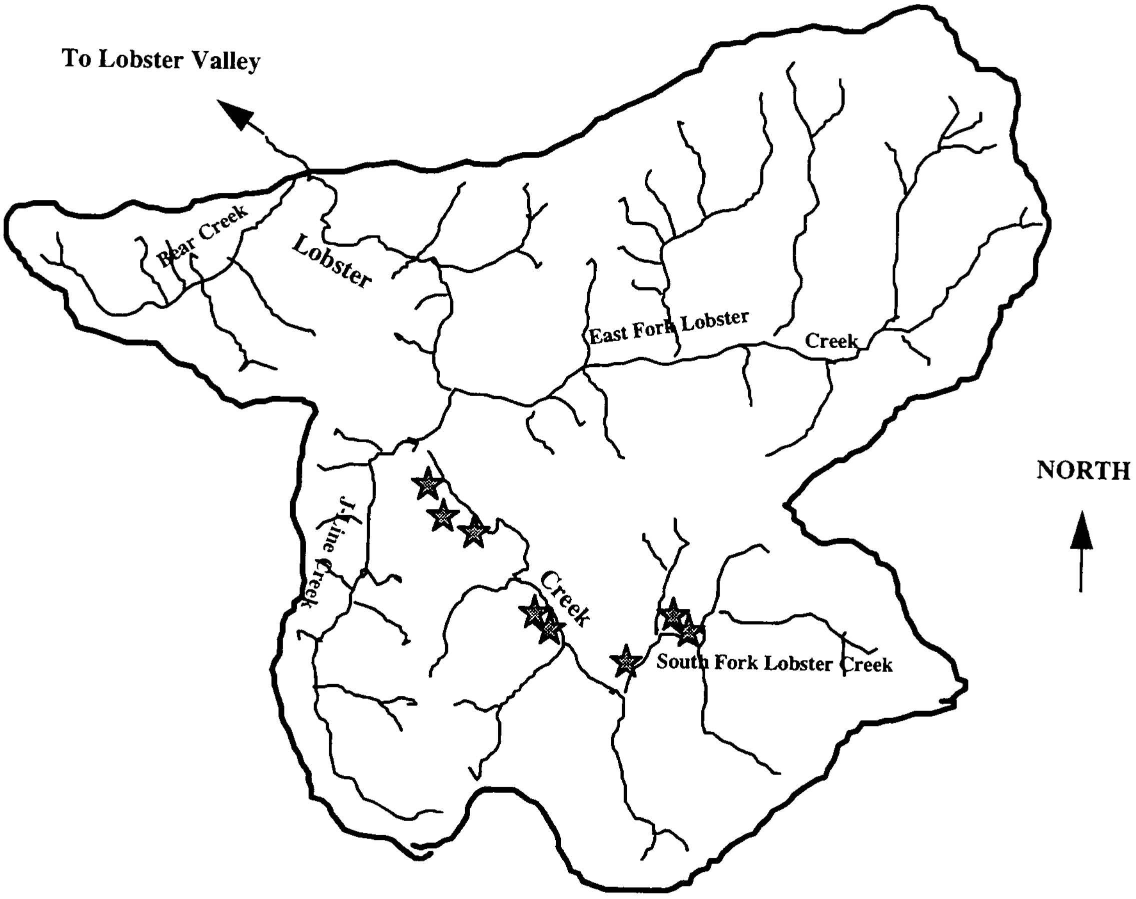
APPENDIX IV, continued

PROPORTIONS OF VARIOUS HABITAT-TYPES

	REFERENCE		RESTORED	
REACH NO.	HABITATS-TYPES	PERCENT OF TOTAL HABITAT	HABITAT-TYPES	PERCENT OF TOTAL HABITAT
3	Riffle over cobble	75	Log-weir pool	50
	Boulder	5	Glide over coble	40
	Backwater Pool Depositional Area	10		
	Riffle over gravel	10		
4	Glide over cobble-gravel	90	Log-weir	2
	Riffle over gravel	10	Log-weir pool	50
			Glide over cobble	48
5	Riffle over cobble	70	Log-weir	2
	Rapid over rubble	10	Log weir pool	90
	Boulder	20	Glide over cobble	8
6	Riffle over cobble	50	Log-weir	2
	Riffle over gravel	15	Log-weir pool	98
	Backwater Pool/ Depositional Area	5		
	Glide over cobble/gravel	30		
7	Glide over cobble-gravel	45	Log-weir	2
	Riffle over cobble-gravel	45	Log-weir pool	90
	Boulder	10	Glide over cobble	8
8	Riffle over cobble-gravel	50	Log-weir	2
	Glide over cobble-gravel	35	Log-weir pool	90
	Glide over gravel	15	Glide over cobble	8

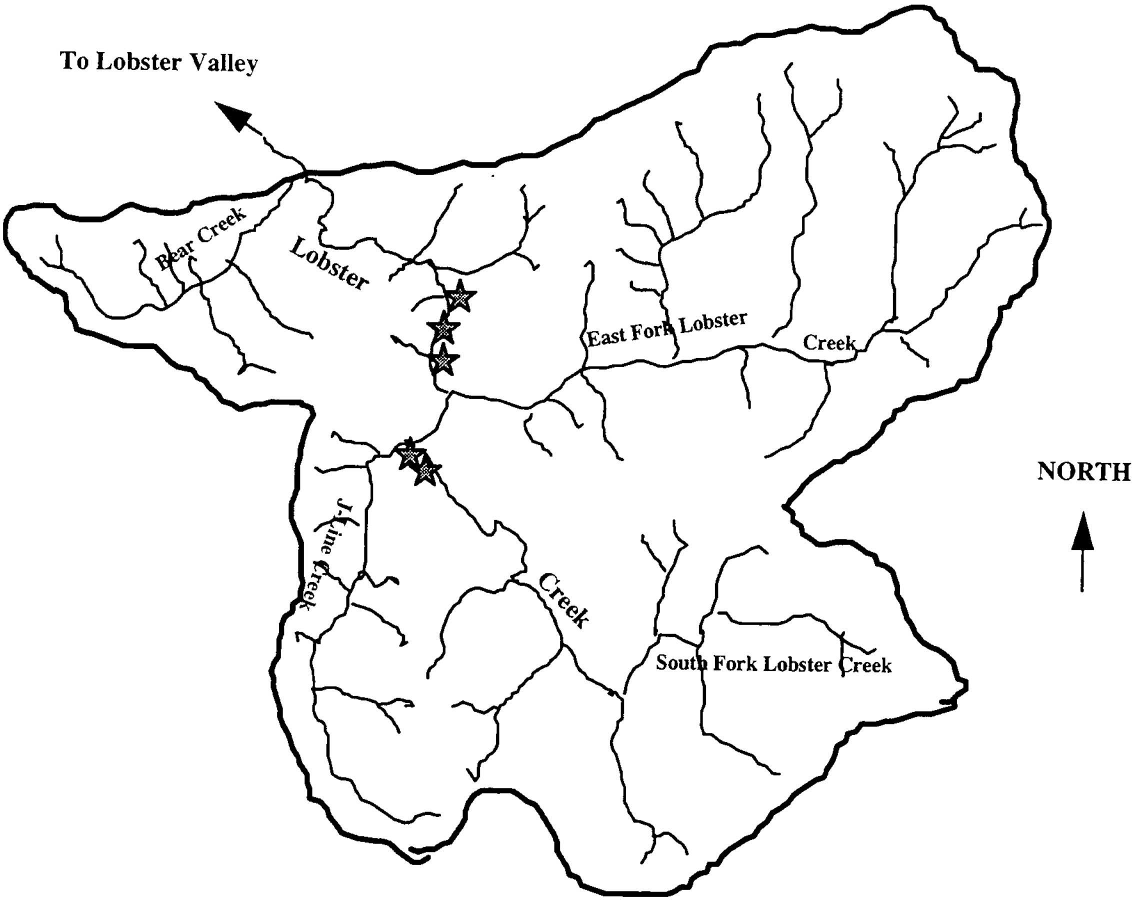
APPENDIX V

LOCATIONS OF ARTIFICIAL AND NATURAL STUDY ALCOVES IN THE UPPER LOBSTER CREEK WATERSHED



★ = Locations of Artificial Alcoves

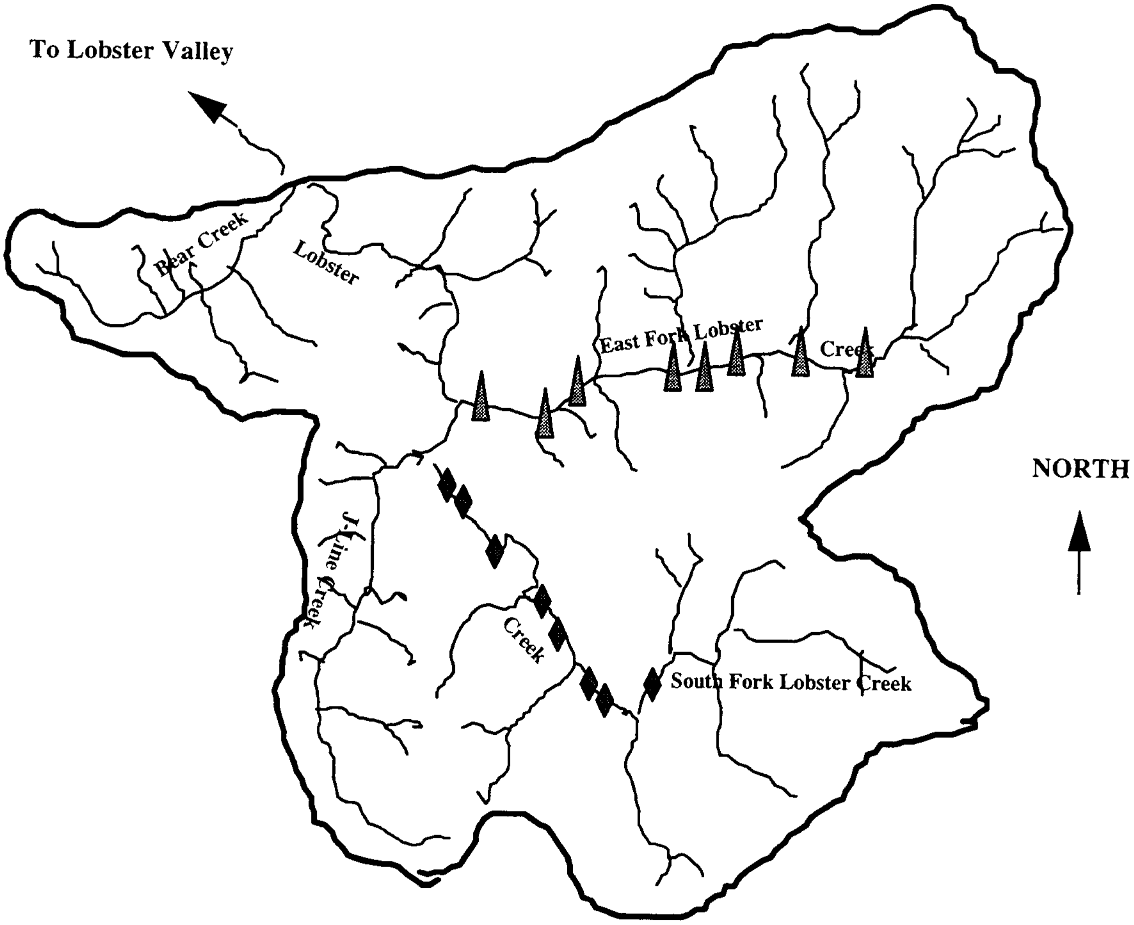
APPENDIX V, continued



☆ = Locations of Natural Alcoves

APPENDIX VI

LOCATIONS OF RESTORED AND REFERENCE STUDY REACHES IN THE UPPER AND EAST FORK LOBSTER CREEK WATERSHEDS



♦ = LOCATION OF RESTORED STUDY REACHES

▲ = LOCATION OF REFERENCE STUDY REACHES

APPENDIX VII

NOTES ON THE EFFECTS OF THE "FLOOD OF 1996" ON NATURAL AND ARTIFICIAL ALCOVES OF UPPER LOBSTER CREEK

During the week of February 2-9, record rainfall combined with rain-on-snow events throughout the Coast and Cascade Ranges resulted in extremely high flows in streams and rivers throughout northwestern coastal Oregon and in the Willamette Valley. Lobster Creek hydrographs for this period were not available from the U.S.G.S. by the time this thesis was going to press, but I thought it was important to at least include informal observations on the effects of this high flow event on the natural and artificial alcoves of Upper Lobster Creek. These observations were made during a visit to Upper Lobster Creek on February 24, 1996.

All of the natural alcoves in the lower study reaches (where Upper Lobster Cr. flows unconstrained through a wide valley) were elminated when the stream cut an entirely new channels adjacent to the old one. However, it appears that several new alcoves were formed in the vicinity. At the time of this visit, water was backing up into a few of the high-flow side channels remnant from the flood, and fish were observed in these pools.

The natural alcoves in the middle study reaches (4N and 5N) appeared unaffected by the flood. If anything, they were slightly deeper (possibly the result of high flows scouring the entrance and permitting greater surface flow from the stream channel into the alcove).

The first two artificial alcoves (1A and 2A) were substantially impacted by the high water levels. A tremendous quantity of fine sediment had been deposited by high flows in these alcoves. These sediments were deep enough to completely cover the alder bundles and large conifer boles that had been placed in the artificial alcoves as cover for fish. At the time of this visit, average depths in these alcoves were only about 0.25 m, and surface interchange between the alcoves and stream channel was completely eliminated. The retention of sediments within the artificial alcoves (in contrast to the natural ones) was probably due to the lack of dynamic suface water exchange between artificial alcoves and the stream channel and the subsequent inability of the alcove to flush.

The fate of artificial alcove 3A is ironic because, of all the artificial alcoves monitored in this study, 3A appeared to be the best-designed alcove in terms of maintaining an intimate hydrologic connection to the stream channel, a consistently clear entrance, and substantial water depths throughout the year. The close association of 3A to the stream channel appeared to be its undoing, as high flows breached the upstream berm of this alcove and completely eliminated it. The alcove was replaced by a huge debris jam, measuring about 25 m wide and 200+ m long.

I was unable to view the other artificial alcoves in the watershed because the Lobster Creek road was blocked by downed trees.

The effects of the “Flood of 1996” on the natural and artificial alcoves of Upper Lobster Cr. highlight the fundamental differences in hydrologic function between natural and artificial alcoves. During the flood, natural alcoves were eliminated due to major channel changes in the wide valley where the natural alcoves were located; however, the dynamic nature of the channel in this area also facilitated the creation of new natural alcoves. In contrast, artificial alcoves were also eliminated but no new ones were created, either because the artificial ones were located along constrained reaches, where channel adjustments were not possible, or because insufficient surface connection to the stream channel prevented the flushing of the deposited sediments.